Contract Report 612

Vulnerability of Illinois Nature Preserves to Potential Ground-Water Contamination

Volume I: Methodology and Initial Assessment

by

Randall A. Locke II
Illinois State Water Survey

Richard C. Berg
Illinois State Geological Survey

H. Allen Wehrmann
Illinois State Water Survey

Michael V. Miller
Illinois State Geological Survey

Donald A. Keefer
Illinois State Geological Survey

Prepared for the
Illinois Nature Preserves Commission

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Illinois State Water Survey
Hydrology Division
Champaign, Illinois

A Division of the Illinois Department of Natural Resources

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ABSTRACT

The Illinois Nature Preserves Commission (INPC) was created by the Illinois Natural Areas Preservation Act in 1963 (ch. 105, para. 701 et. seq.), with the mission to *"assist... landowners in protecting high quality natural areas and habitats of endangered and threatened species in perpetuity, through voluntary dedication of such lands into the Illinois Nature Preserves System."* Dedication as a nature preserve provides strong legal protection. For example, penalties for damaging a nature preserve range from a Class A misdemeanor to $10,000 per day in civil penalties. As of December 1996, the Illinois Nature Preserve System consisted of 261 nature preserves which encompass over 35,000 acres (14,200 hectares) in 73 of the 102 Dlinois counties.

A significant threat to nature preserves (and other areas with high quality natural communities) is adjacent land use. Variability in adjacent land use generally depends on preserve size and location. Frequently, many different land uses surround a single nature preserve. Potential ground-water contaminant sources include: dumping within or near a preserve, residential septic systems, roads where deicers are used, agricultural fields or feedlots, leaking impoundments or storage tanks, and certain industrial and commercial activities. Unfortunately, the lack of baseline data at most preserves prevents the detection of water quality degradation from off-site activities.

During this study methods were developed and utilized to assess nature preserve sensitivity and vulnerability to potential ground-water contamination. First, a shallow ground-water sensitivity map of the state (1:500,000) was prepared using GIS techniques. It predicts the potential for movement of contaminants from the surface into shallow ground water based on soil leaching characteristics and depth to the uppermost aquifer. Two hundred seven nature preserves were screened and nearly half of them were categorized as having high or very high sensitivity to ground-water contamination.

Second, site surveys were conducted at the 85 nature preserves which were expected to be most sensitive to ground-water contamination. Hydrologic, geologic, and land-use information was collected for the sites and surrounding areas prior to the surveys. This data was used during the surveys and can be used for future interpretations and comparisons. Roughly 30% of the sites were classified as having moderate to high or high vulnerability. The development and use of a field evaluation form facilitated site surveys and the subsequent entry of field data into an electronic database. These types of surveys should be conducted at all nature preserves to provide a standard set of background information for future decision making.

Third, the geology and hydrology of Spring Grove Fen Nature Preserve in McHenry County were characterized in greater detail. Test drilling was conducted and 10 observation wells were installed. A total of sixty-four sets of ground-water and surface water samples were collected between August 1995 and October 1996 and analyzed for a minimum of 35 constituents. Increased chloride concentrations (up to 121 mg/L) were observed in and upgradient of the preserve. Use of deicers on nearby roads may be responsible for an increase in chloride of over 500% at well SG-1a. Low concentrations of alachlor metabolites ($< 3\ \mu g/L$) were seen in observation wells and in Nippersink Creek. Low concentrations of triazine residues ($< 1\ \mu g/L$) were also seen in Nippersink

Creek. Chemical data at Spring Grove Fen supports the assessment of the site being highly vulnerable to contamination. This type of chemical sampling is important to establish existing water quality at preserves for comparison to future conditions.

Information collected during this study is intended to facilitate petitions for state designation of ground water associated with a nature preserve as a Special Resource Ground Water. As stated in the Illinois Administrative Code (Title 35, Part 620.230), Special Resource Ground Water is: a) *"demonstrably unique...,"* or b) *"vital for a particularly sensitive ecological system...,"* or c) *"groundwater that contributes to a dedicated nature preserve...."* Such a designation may then provide an additional level of protection against destruction or degradation of nature preserves.

ACKNOWLEDGMENTS

Both past directors, Gretchen Bonfert and Brian Anderson, and the current director, Carolyn Grosboll, of the Illinois Nature Preserves Commission were instrumental in the development of project funds and management of the project. Commission staff (Randy Heidorn, Celine D'Onofrio and Tammie McKay) also helped gather information.

This project was funded by 319 (non-point source pollution) grant money from the United States Environmental Protection Agency which was administered by the Illinois Environmental Protection Agency.

We appreciate the participation of area residents (Mr. and Mrs. Clary, Mr. and Mrs. McCarthy, Mr. and Mrs.. Oxtebbe, Mr. Regnier, Mr. Wu, and Mr. and Mrs. Young). Their cooperation allowed us to drill wells and collect water samples near Spring Grove Fen. We are grateful to J. Maichle Bacon and Patrick McNulty of the McHenry County Department of Health for analytical services of the Department.

Many people from the ISWS and ISGS also provided effort and insight for this project. Scott Meyer spent several weeks in the field as part of an evaluation team. Mary Mushrush developed several databases, generated and compiled GIS data, and helped develop the field evaluation forms. Joe Karny helped significantly with the quarterly sampling at Spring Grove Fen. Bryan Coulson drilled and helped construct observation wells at Spring Grove Fen. Madalene Cartwright gathered and verified well records from the ISGS files in addition to covering other details of the project. Dan Barnstable helped greatly with field efforts at Spring Grove Fen and data gathering for the 85 sites that were visited. Staff from the ISWS analytical chemistry division (Loretta Skowron, Dan Webb, Lauren Sievers, Saada Hamdy) helped immensely with their service and input relating to sampling at Spring Grove Fen. Lisa Xu gathered well records and digitized preserve boundaries for use in statewide screening. Patti Hill helped prepare this report.

District Heritage Biologists of the Illinois Division of Natural Heritage and Natural Resource Conservation Service District Offices (directors and resource conservationists) identified local concerns at nature preserves.. Rebecca Gee of the Illinois Chapter of The Nature Conservancy gathered information relating to selected nature preserves. Wayne Schennum of the McHenry County Conservation District and Tom Nuzzo from the District 1 Office of the Illinois Department of Transportation helped expedite our field work at Spring Grove Fen. Mike Thurman of the United States Geological Survey in Lawrence, Kansas conducted pesticide metabolite analyses on samples from Spring Grove Fen. Todd Thompson of the Indiana Geological Survey provided StratCol software and technical support.

Many people have added their effort and knowledge to this study and we are greatly appreciative to all who have been involved.

INTRODUCTION

Illinois Groundwater Protection Act

The Illinois Groundwater Protection Act of 1987 (IGPA) required the promulgation of ground-water quality standards which were adopted in November 1991. The standards recognize the uniqueness of some ground water by providing a classification called *Special Resource Ground Water*. As stated in the Illinois Administrative Code (State of Illinois, 1994), Special Resource Ground Water is: a) *"demonstrably unique...,"* or b) *"vital for a particularly sensitive ecological system...,"* or c) *"groundwater that contributes to a dedicated nature preserve...."* Ground water that contributes to a nature preserve may be given Special Resource Ground Water status by submitting the following material to the Illinois Environmental Protection Agency (IEPA) for review:

a) A general description of the site and the surrounding land use;

b) A topographic map or other map of suitable scale denoting the location of the dedicated nature preserve;

c) A general description of the existing ground-water quality at and surrounding the dedicated nature preserve;

d) A general geologic profile of the dedicated nature preserve based upon the most reasonably available information, including but not limited to geologic maps and subsurface ground-water flow directions; and

e) A description of the interrelationship between ground water and the nature of the site.

To date, no Special Resource Ground Water designations have been made. While the standards outline a process for designation, the specific steps for petitioning and designation need to be clarified.

Purpose

While the penalties for damaging a nature preserve range from a Class A misdemeanor to $10,000 per day in civil penalties, the lack of compiled information about existing ground-water conditions prevents the detection of damage caused by off-site activities. One of the greatest threats to the integrity of nature preserves is adjacent land use. This is particularly true in areas where substantial land-use changes have occurred or are planned. Residential, industrial, commercial, municipal, and agricultural land uses pose problems to the sustainability of Illinois' nature preserves.

Ground water or surface water that is contaminated by rural or urban land use is a potential threat to flora and fauna in nature preserves. Preserves are especially sensitive to contamination when ground water is transferred rapidly to them (i.e., they are associated with permeable geologic materials and are downgradient) from off-site sources. These types of preserves often contain surface water features resulting from ground-water discharge (e.g., seeps, springs, bogs). The successive degradation of a preserve due to continued development or land use change nearby is a concern. Presumably, the impacts of urbanization around preserves will continue to be identified in years to come. Although the study of surface water relationships at nature preserves is recognized as important, this project was specifically designed to identify threats posed by potential changes in ground-water quality.

While there is particular concern about the effects on preserves from nonpoint pollution sources such as septic systems, lawns, agricultural lands (especially areas of row cropping), and roads, very little information exists on which decisions can be based. The Illinois Nature Preserve Commission (INPC) has estimated that 85 (nearly one-third) of the preserves include unique and sensitive flora or fauna that rely on ground-water discharge to exist. The ground waters contributing to these and other nature preserves within the Illinois Nature Preserve System (INPS) have the potential for inclusion as Special Resource Ground Waters. Information gathered during this project is expected to be used to facilitate such designation.

Unfortunately, data has not been available for most of the preserves which adequately documents past and present ground-water quality or determines which preserves are the most vulnerable to potential ground-water quality or quantity changes. This report identifies the preserves which are most vulnerable to potential ground-water quality changes due to present surrounding land uses. For preserves to be effectively managed and protected, it is essential that information describing the natural character of preserves as well as their relationship to local hydrogeology be collected, evaluated, and maintained.

Scope

To assess the vulnerability of Illinois' nature preserves and establish the means to protect ground-water resources of preserves, the Illinois State Water Survey (ISWS) and the Illinois State Geological Survey (ISGS) performed three main tasks:

1) Determined the sensitivity of the 207 sites in the INPS to ground-water contamination by conducting a statewide screening of sites based upon ground-water sensitivity criteria using geographic information system (GIS) technology;

2) Evaluated the vulnerability of 85 nature preserves, which were identified by the INPC to have areas of ground-water discharge to the surface, through compilation of existing hydrogeologic data and on-site reconnaissance; and

3) Selected one nature preserve identified as highly vulnerable to ground-water contamination, described the hydrology and geology in detail, and collected water levels and samples on a quarterly basis for over one year.

Activities under task one were conducted to develop a screening tool that would identify the need for more detailed work at the preserves based on their sensitivity. GIS sensitivity classifications and site vulnerability classifications (task two) were compared. This was important in identifying the strengths and weaknesses of these methods for assessing regional or local characteristics. The development of this technique also provides a way to (re)evaluate site sensitivities as the ground-water sensitivity map is refined or as more sites are added to the INPS.

For task two, available hydrogeologic information was compiled for 85 nature preserves. Such information included, where available, regional and local geologic maps and cross-sections, geologic well logs, ground-water quality records, and ground-water level data. Each preserve was visited and an appraisal was made of the potential threats posed to ground water entering the preserve. The accumulated information will be stored at one of the surveys and transferred to the INPC in two forms; a site folder for each of the 85 sites and an electronic database. Both of these products are described in this report. The site folders were used as the primary archive for site information and may be valuable in requesting Special Resource Ground-Water designations. The computer database provides INPC staff and others with summarized information contained in the individual site folders. The information in the database can be examined by a wide variety of search criteria for future evaluations and summaries. Much of the data contained in the database is summarized in this report (Volume I) and presented in its entirety in Volume II.

For task three, Spring Grove Fen in McHenry County was selected for intensive site-specific hydrogeologic investigation. The geology, hydrology and surrounding land use were described in detail. This type of site-specific data collection is important in documenting local flow directions, ground-water chemistry and geologic framework. The characterization done a Spring Grove Fen can be an example for subsequent data collection efforts at other preserves. Similar activities would be crucial where baseline data are needed to establish current and future ground-water conditions. Such efforts may be the Commission's major defense in protecting these preserves from future degradation.

STATEWIDE SENSITIVITY SCREENING

Nature Preserve Boundaries

In the Spring of 1995, a GIS coverage of the nature preserve boundaries was obtained from the Illinois Natural History Survey. This coverage did not contain all of the boundaries that were a part of the INPS at that time. During the course of this study, approximately 25 preserve boundaries were added by digitizing boundaries which were plotted on 1:24,000 scale topographic maps. The boundaries that were added were those of preserves chosen for site surveys which were not already in the GIS coverage. A representation of the resulting coverage that was used for all screening activities is shown in Figure 1. It should be noted that over 50 sites currently in the INPS have not been screened by the methods described below.

Shallow Ground-Water Sensitivity

A sensitivity model was developed to make regional predictions of the sensitivity of ground water to contamination in and around nature preserves. The project objectives required a quick screening tool that used parameters that were readily available for all sites. For this reason, the model used existing statewide soils and geologic maps at a scale of 1:250,000 to describe the hydraulic characteristics of soils and the occurrence of *aquifers*. An aquifer is a permeable geologic unit that can transmit significant quantities of water. The source data were a statewide soil association map and database (USDA, 1991) and an ISGS statewide stack-unit map (Berg and Kempton, 1988).

Keefer (1995) has made interpretations of the U.S. Department of Agriculture's State Soil Geographic (STATSGO) database with respect to water transport. In those interpretations, indices were developed to describe soil characteristics. The parameters selected for use in the present sensitivity model included the travel time index and drainage class index.

The travel time index is an indication of the rate at which water moves through the entire soil profile. It was calculated by dividing the thickness (in inches) of each soil horizon by the hydraulic conductivity (in inches/hour) of that horizon. Individual horizon values (in days) were then summed to provide a single value for each soil. An analysis of the travel time values was made for all mapped soils and was used to develop a five-category classification system (Table 1).

The drainage class index provides a rough measure of the depth to the seasonally high water table for each soil profile. This index was developed by generalizing the natural drainage class categories included in the soil association map and database. The USDA defines 7 categories of natural drainage class, to which the soil association map adds 4 transitional categories. These 11 categories were regrouped into 5 categories (Table 2).

Figure 1. Location of 207 nature preserves

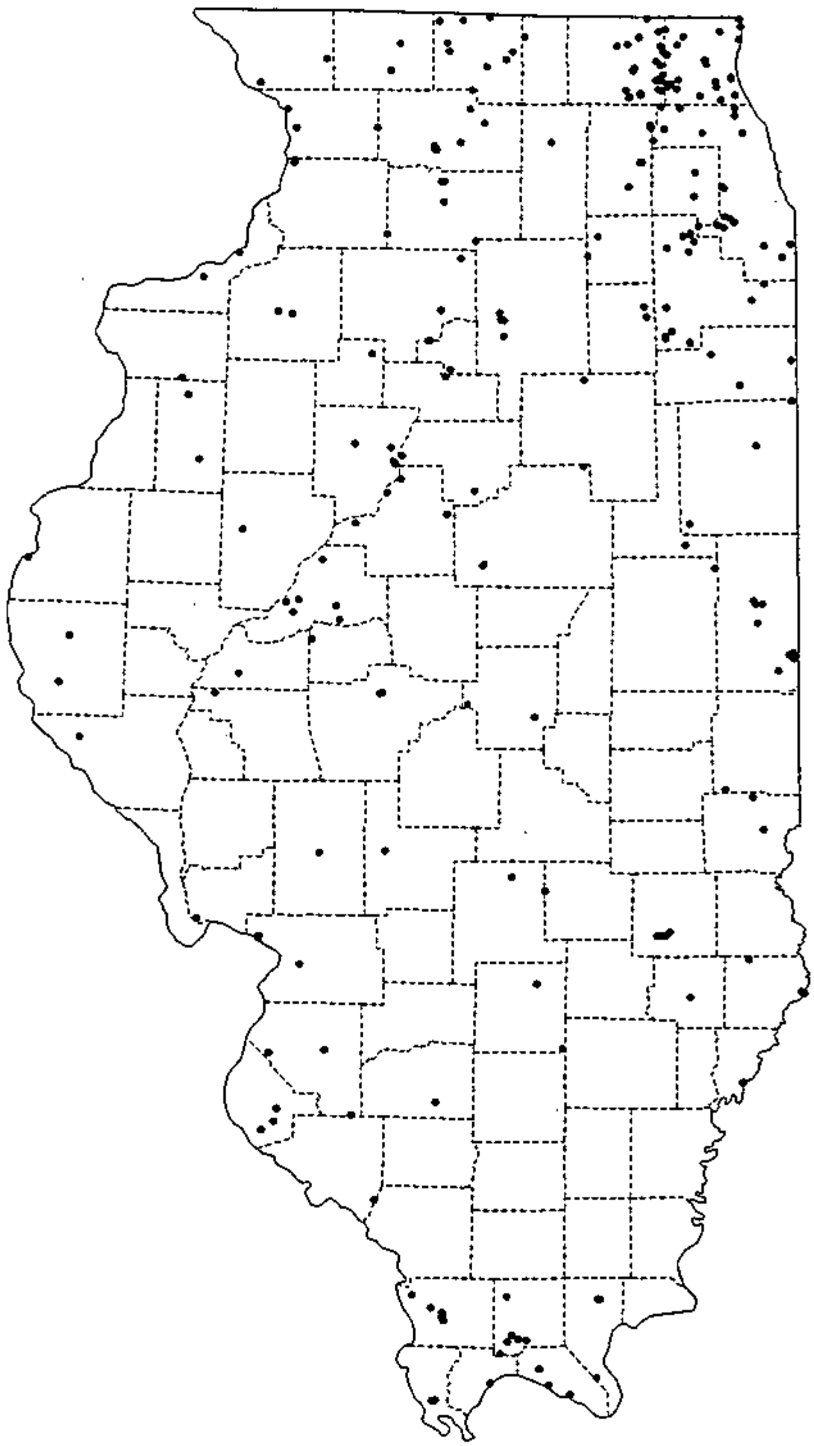


Table 1. Travel time index (from Keefer, 1995)

Travel time index	Horizon thickness / hydraulic conductivity (days)
Very fast	<1.5
Fast	1.5 to 3.0
Moderate	3.1 to 14.0
Slow	14.1 to 28.0
Very slow	>28.0

Table 2. Drainage class index (from Keefer, 1995)

Drainage class index	Natural drainage class
Excessive	Excessive Somewhat excessive Somewhat excessive to well
Well	Well Well to moderately well
Moderate	Moderately well
Poor	Somewhat poorly Somewhat poorly to poorly
Very Poor	Poorly Poorly to very poorly Very poorly

These two indices, drainage class and travel time, were then combined and interpreted to provide a relative measure of the drainage, or water flux, characteristics of soils. For this report, Table 3 shows how the travel time and drainage class indices were combined to define water flux categories. A thorough discussion of the method used to define the 6 water flux categories is available in a previous publication by Keefer (1995).

A statewide map of surficial geologic materials was used to describe the occurrence of shallow aquifers (Berg and Kempton, 1988). This map shows the succession of geologic materials

Table 3. Water flux categories (adapted from Keefer, 1995)

Water flux	Travel time index	Drainage class index
Excessive	Very fast or fast	Excessive
Somewhat excessive	Very fast or fast	Well or moderate
	Moderate	Excessive or well
High	Moderate	Moderate or poor
Moderate	Slow or very slow	Excessive to moderate
	Very fast or fast	Poor
Limited	Moderate to very poor	Poor or very poor
Very limited	Excessive to moderate	Very poor

in their order of occurrence from the surface to a depth of 50 feet. Therefore, aquifers (e.g., sand and gravel, fractured limestone and dolomite, and sandstone) are delineated. This map is based on information from more than 25,000 well logs. As discussed by Keefer (1995), this geologic materials map only identified deposits that were either 5 feet thick, or were present in well logs over an area of at least 0.5 square miles. Aquifers identified from this map were therefore limited to these same criteria.

These two maps, the STATSGO map and statewide geologic map, were combined and interpreted according to the model in Table 4 using ARC/INFO, a computerized Geographic Information System (GIS) software package. This model combined parameters previously discussed to define four different categories of shallow ground-water sensitivity to contamination (Table 4).

Table 4. Categorical model for predicting ground-water sensitivity to contamination

Ground-Water Sensitivity	Soil Drainage (Water Flux)	Depth to Uppermost Aquifer (ft)
Very High	Excessive - Moderate	Within 20
High	Excessive - Somewhat Excessive	20 - 50
	Excessive - Somewhat Excessive	Not within 50
Moderate	Limited - Very Limited	Within 20
	High - Moderate	20 - 50
	High - Moderate	Not within 50
Limited	Limited - Very Limited	20 - 50
	Limited - Very Limited	Not within 50

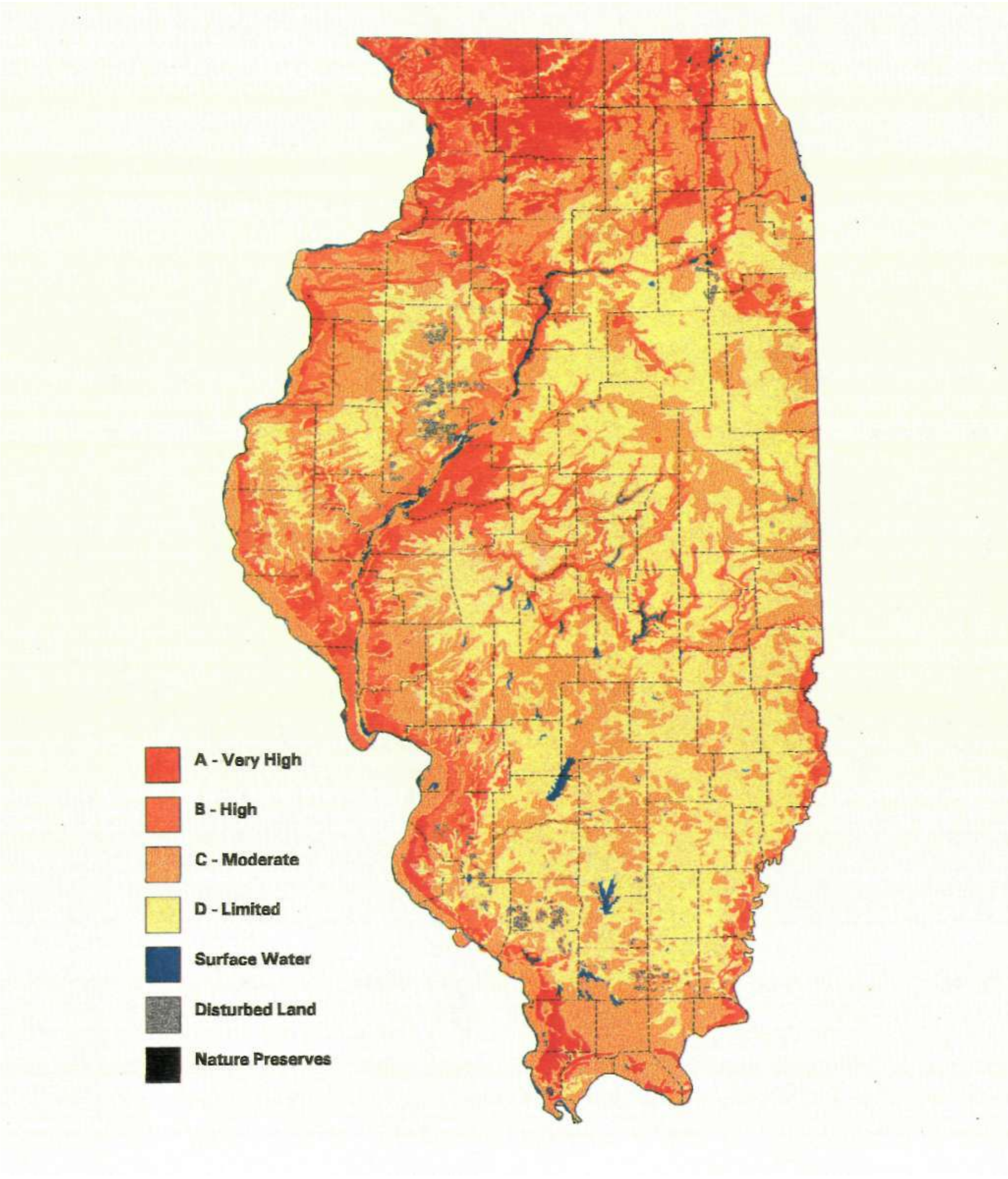
This ground-water sensitivity model differs significantly from other efforts which evaluated aquifer sensitivity to contamination. In this study, soil drainage characteristics were given more weight in affecting the potential for ground-water contamination than the presence of aquifers. Recent research by Berg et al. (1997, in review) supports the notion that soil water flux is closely related to surface water discharge characteristics at low-flow conditions. In addition, areas with aquifers within 20 feet of land surface were assigned more importance than areas with aquifers between 20 and 50 feet or areas without aquifers. This is based on an assumption that aquifers within 20 feet from the surface are more likely to be important to the hydrology of the nature preserve (i.e. providing shallow ground-water discharge) than deeper aquifers. Aquifers within 20 feet were also weighted more because they represent a more available resource as compared with ground water in non-aquifer materials. The faster transport characteristics of the aquifer materials increase the likelihood that contaminants will be transported to wetlands within nature preserves from off-site sources.

The model discussed above defines 4 broad categories of ground-water sensitivity that are based only on intrinsic material properties. Information regarding the distribution of potential contaminant sources was not used, primarily because of the difficulty in reliably identifying potential sources at a small scale. In addition, water quality information was not available to evaluate the appropriateness of these divisions. This model is, therefore, not yet validated, and any applications of this model should take this into account.

Maps of soil associations and geologic materials in the upper 50 feet were used with this model to produce the map, "Shallow ground-water sensitivity to contamination surrounding nature preserves," (Figure 2). The generalities included in the soil and geologic maps were such that many natural variations in the thickness and character of soil and geologic materials could not be identified. These limitations are generally identified in the documentation accompanying the maps. While these generalizations do not affect the utility of the maps in predicting the occurrence of map units, they can affect prediction of the occurrences of any interpreted characteristics of the map units. For example, a geologic map which identifies units based on their thickness and lateral occurrence can be a reliable predictive tool. This same map, however, will not be as reliable for predicting the water flow or contaminant transport characteristics of the mapped deposits.

The sensitivity map is an appropriate tool for: 1) statewide or regional prioritization efforts and 2) screening evaluations of individual locations (e.g., nature preserves). The potential impact of unidentified source-map variabilities on ground-water sensitivity predictions, however, is potentially large enough to make this map unreliable as the only predictive tool for sensitivity at specific locations. Because of this potential impact, any situations that depend on highly accurate predictions of sensitivity should also be based on site-specific soils and geologic information.

Figure 2. Shallow ground-water sensitivity to contamination surrounding nature preserves



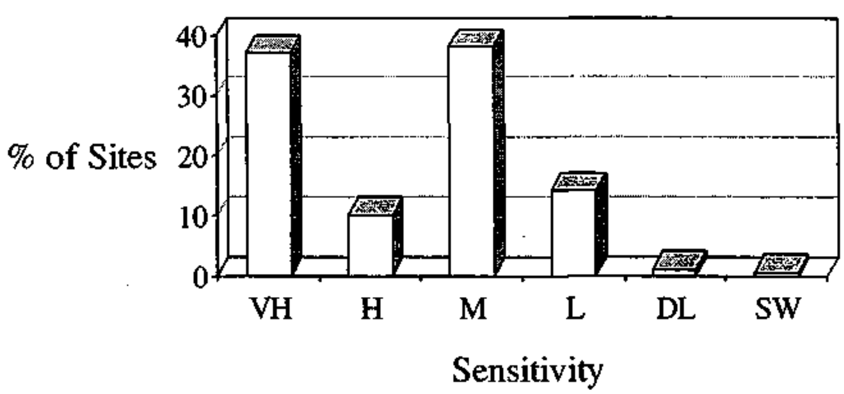
Interpretation of Preserve Sensitivity

Both *dedicated lands* and *surrounding lands* were screened similarly for their sensitivity to ground-water contamination. Dedicated lands were areas within dedicated preserve and buffer boundaries. Surrounding lands were areas within *Vz* mile of preserve and buffer boundaries.

Dedicated Lands

Polygons representing the boundaries of 207 nature preserves (and their buffers) were superimposed on the shallow ground-water sensitivity map. To interpret the sensitivity at a preserve, several steps were needed to consolidate results. Commonly, the boundaries for a single preserve were divided into several polygons because of linear features (e.g., streams or easements) which crossed the preserves. It was then necessary to sum the occurrence of mapped sensitivities in several polygons and report them for a single preserve. For example, sites that were mapped with an area of more than 50% of very high sensitivity were classified as very highly sensitive. For the other ground-water sensitivity categories (high, moderate, limited, disturbed land, and surface water), a site was classified according to the category which made up ≥ 51% of the site's area (Figure 3).

Figure 3. GIS sensitivity classification of 207 nature preserves

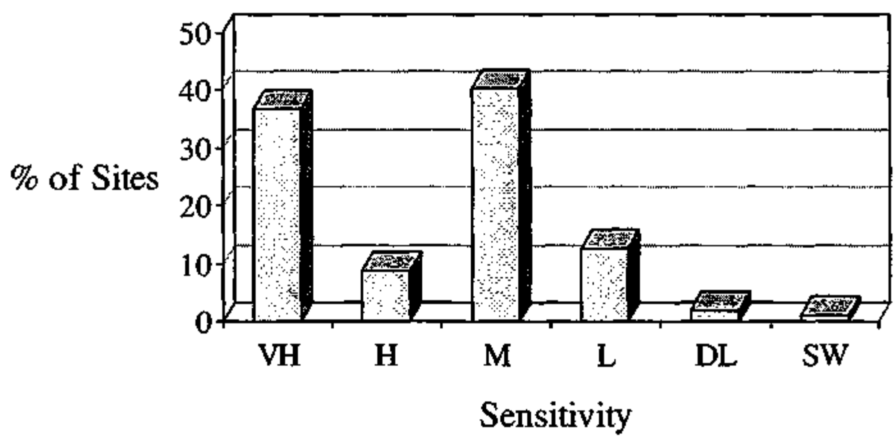


This statewide screening indicates that about half (48%) of the sites have high or very high sensitivity to ground-water contamination. It is of interest that the very high and moderate categories account for 85 percent of the sites screened. This strongly bimodal distribution may be due to the presence of two distinct groups of nature preserves; one group which occurs in topographically low areas like floodplains (i.e., areas of greater sensitivity because of coarser grained deposits), and one group which occurs in the uplands (i.e., areas of lower sensitivity).

Surrounding Lands

The sensitivities of the surrounding lands are very similar to the preserves (Figure 4). Again, nearly half of the sites were classified with very high or high sensitivity. It is apparent that the overall distribution of sensitivity for the preserves mimics that of the surrounding areas. Appendix A lists 85 preserves which were visited (described later) and shows a breakdown of the classified sensitivities for a preserve or surrounding area (very high, high, moderate, limited, surface water, disturbed land, and slivers). Generally, individual preserve sensitivity tends to be closely related to the sensitivity of the surrounding area. The ground-water vulnerability rating (described later) is also listed.

Figure 4. GIS sensitivity classification of areas surrounding 207 nature preserves



INITIAL SITE VULNERABILITY ASSESSMENTS

While statewide screening was used to categorize the sensitivity of preserves based on soils and geologic information, additional information was needed to determine the vulnerability of selected preserves. Vulnerability incorporated both an area's sensitivity and a determination of potential sources from surrounding land uses. A list of 85 preserves with significant ground-water/surface-water features (e.g., seeps, springs, bogs, fens, marshes) was compiled by the INPC. In general, these sites:

- ► cover 6155 hectares (15,211 acres) not including 240 ha. (594 ac.) of buffers
- ► account for 45 % of the total INPC acreage (as of 8/96)
- ► occur in 34 counties
- ► cover 178 primary sections (defined on p. 17)

The hydrologic conditions that create and sustain these features are geologically controlled and are often associated with ground-water discharge. It was anticipated that these sites would rank higher in vulnerability because of their unique hydrology. Site surveys were conducted to better identify the local geologic framework and hydrologic conditions that could contribute to the transport of contaminants, as well as, to identify potentially adverse land-use activities surrounding the sites.

Collection of Available Hydrogeologic Data

Before site surveys were conducted, background data was collected from several sources and organized for each of the 85 sites in individual site folders. Each folder was indexed with a contents list (Figure 5). The minimum information included:

- ► the site description and boundary from the 1995 Directory of Illinois Nature Preserves,
- ► a topographic map,
- ► a county soils association map,
- ► ISWS/ISGS well logs with geologic descriptions (described below), and
- ► a representative geologic column constructed for this project.

In addition, the following information was included when available:

- ► aerial photos, plat maps, or park maps,
- ► ISGS geologic descriptions of test holes and sample sets,
- ► water-quality data from the ISWS paper records,
- ► other hydrogeologic data (e.g., from construction plans, environmental impact assessments, and other research),
- ► INPC/IDNH data (described below),
- ► U.S. NRCS Resource Conservationist comments (described below), and
- ► IDNH District Heritage Biologist comments.

Figure 5. Contents list for individual site folders

File Contents for

Nature Preserve

Surface Maps of Preserve and Surrounding Area:
____Topographic maps___________________Plat maps
____Soil maps___________________________Park maps
____Aerial photos________________________Other :

Water Quality:
____SWS Analyses w/ drillers' logs How many?____
____Other SWS water analyses How many?____
____Additional water analyses:

Geology:
____Geologic map (map name:____________________, scale =______________source:_______)
____Geologic description in dedication proposal
____Soils description in dedication proposal
____Drillers' logs selected How many?_______Locations verified?____
____ISGS Logs How many?_______Location_____and interpretation_____verified?
____Additional logs:

Potential or Existing Land Use Threats (related to development) Reported by:
____County SWCD:
____Site steward:
____District Heritage Biologists:
____Other:________________________:

Information from the Nature Preserves Commission "Preserve Files":
____Dedication proposal (partial)
____Specific site studies:
____Threats related to ground water:
____Other:

Information from the Division of Natural Heritage Site Basic Report Files:
____Original INAI print outs (partial)
____Other:

General Description of:
____Site and surrounding land use
____Existing ground-water quality at and around the preserve
____Geology and ground-water hydrology of the preserve
____Estimated ground-water flow directions in the preserve
____Relationship between the geohydrology and the preserve

ISWS/ISGS Data

The Water and Geological Surveys maintain drilling records from pre-1900 to the present for drinking water, observation, and oil wells, in addition to, records of engineering borings and test holes. While the information available for an individual record varies, these data are collectively referred to as *well records*. It is estimated that the Surveys have approximately 700,000 well records. It has been estimated that Illinois may have 1.5 million private wells, of which, the Surveys have a records for roughly one-fifth. While these collections are by no means complete, they provide the state with the most comprehensive source of information on well location and characteristics (e.g, depth, construction, and materials drilled through). This information is filed using Township, Range and Section designations.

The Water Survey's Private Water Well Database (PWWD) was searched for geologic and chemical information in primary and secondary sections. For this study, *primary sections* are those land areas containing a preserve or associated buffer acreage, while *secondary sections* are those directly adjacent to primary sections. The information in the PWWD has been entered verbatim from data sources including: well logs submitted by drillers, chemical analysis reports, well sealing forms, well inventory forms, and other special projects. The accuracy of this data is controlled by those who submit the forms and is unverified. The query on the PWWD was used to approximate what was available in the ISWS Basic Data Files. The Basic Data Files were the main source of geologic information collected for the 85 sites that were visited.

Once the data was retrieved and copied, areas were identified that had either too little or too much information. The number of records available for the primary and secondary sections varied widely from zero to over 500. In most cases where too few records were available in the ISWS Basic Data Files, supplemental information was assembled from ISGS well records. Records were then copied and filed in the site folders.

For at least five areas, over 60 well records were available. For that reason, records were reviewed for both individual and group characteristics (Figure 6) and those that were not reliable or adequately descriptive were not used. The ideal geologic logs were those where a detailed geologic description had been previously done by an ISGS staff member and where an accurate well location was field verified. A search of the ISGS well record database was done to retrieve detailed core descriptions not available from the ISWS Basic Data Files.

Information from all well records in the site folders were entered into the ISGS Conquest electronic well database. Well records were verified by checking the recorded location on a county plat map. If the well owner's name matched the land owner's name, the well location was considered verified. While not as accurate as field verification, plat verification was a feasible task to increase data quality for this study. Where possible, ten well records were plat verified for each site. Well records were then split into two categories; those within 1 mile of the preserve and those farther away.

Figure 6. Criteria for choosing well records within the site folders

- I. Desired Information for Individual Records
  - A. Geologic Description
    1. complete and unambiguous material descriptions
    2. unit boundary accuracy (i.e., thicknesses aren't consistently in multiples of five or ten)
  - B. Location Description
    1. unambiguous location descriptions
    2. level of description to 3 quarter sections (flexible depending on available information)
    3. verifiable locations
       - a. by plat book
       - b. by telephone book
       - c. by field inspection (not feasible for this project)

- II. Desired Group Characteristics of Compiled Records
  - A. Depth of Hole
    1. deeper holes for more regional geologic information
    2. shallower holes for more local geologic information related to surficial geologic units
  - B. Location of Records
    1. logs in uplands and lowlands where both are present
    2. even horizontal distribution of logs

Records of water analyses were also obtained from the PWWD. For 24 of the 85 areas, there were between 2 and 11 chemical analyses available. However, these were generally analyses of water from boiler facilities which are not representative of the water chemistry at preserves.

Representative Geologic Columns

Representative geologic columns were made for the 85 nature preserves by using the software package StratCol (version 0.29). This data is presented in Volume II of this report. These columns were constructed to a depth of 100 feet and are stratigraphic interpretations of representative well records that occur at and near the preserves. A general geologic profile of a preserve based on the available information was needed for evaluating the sensitivity of the nature preserve on a local scale.

INPC/IDNH Data

Visits were made to INPC and IDNH to collect hydrogeologic, land use, and site-accessibility data. The Directories of Illinois Nature Preserves (McFall, 1991, 1995a and 1995b) greatly helped information gathering. Maps shown in the directories were used as a source for site boundary information and site location (i.e., Township, Range, and Section). As the project started, the 1991 Directory was available, but it did not list 25 sites that had been chosen for site visits. For these, boundary and location information was gathered from the INPC. The INPC maintains records for each site within the INPS. These files include but are not limited to:

- dedication proposals (which may contain site history, geology, and soils descriptions),
- correspondence and detailed information about developments near a preserve,
- alterations to a preserve,
- management plans,
- references to scientific investigations, and
- research reports.

IDNH maintains data on sites identified in the Illinois Natural Areas Inventory (INAI) in the Site Basic Report (SBR) Files. The INAI was a 3-year project to find and describe natural areas for the Illinois Department of Conservation. Methods for finding natural areas consisted of compiling available information, examining maps and aerial photos, aerial surveys, and on-site inspections. As many as 90 items of information were compiled for the significant sites (White, 1978). Information available irt the SBR Files includes:

- original INAI field sheets (ca. 1975),
- a computer print out of data collected during the INAI,
- INAI boundaries on xeroxed topographic maps (1:24,000 scale),
- overlays of site boundaries and high quality communities (1:24,000 scale),
- species inventories,
- field biologist visitation records,
- technical articles,
- unpublished reports, and
- site master plans.

Other Data

Comments were solicited from local natural resource personnel on land use and land-use changes. Both IDNH District Heritage Biologists (DHBs) and U.S. Natural Resource Conservation Service (NRCS) personnel were sent letters (Appendix B) asking for information on land use surrounding the preserves. Thirty-three NRCS offices and twelve DHBs were solicited and responses were received from each group concerning nearly 70 percent of the sites. Both the NRCS and DHB comments were noted on the index sheet of each site folder so that the field crews could address them during their site surveys.

The Illinois Chapter of the Nature Conservancy has information regarding volunteer site stewards who conduct many activities at nature preserves and natural areas. While the information is not a complete listing of the stewards, it is nonetheless valuable. We intended to send the site stewards a letter similar to that sent to the NRCS and DHBs, but did not because of the large number of stewards and our incomplete information about them. In the future, it is suggested that the stewards be solicited for their knowledge prior to any additional site evaluation. Other people or agencies that could provide useful information should also be considered (e.g., landowners, County Forest Preserve Districts, and City Park Districts).

Site Surveys

Sites surveys began in the southern and central portions of the state near the end of January 1996 and continued until September 1996. Two-member teams with extensive individual field experience in geologic mapping and identification, wetland hydrology and hydrologic interpretation, and water quantity and quality investigation visited the sites and took detailed notes. Teams were in the field approximately five weeks and their field interpretations were aided by the use of the previously compiled information noted above. During an average day in the field three to four sites were evaluated.

Field Evaluation Form

An evaluation form (Appendix C) was developed prior to field activities to unify note taking and interpretations as well as facilitate later input of field data into an electronic database. Trial evaluations were conducted jointly on three sites in Vermilion County during the summer of 1995. Since evaluations would be conducted at 85 sites by multiple field teams, this exercise provided personnel with a common reference of how to conduct evaluations. The form subsequently went through several revisions to better facilitate field use. In general, it was used to document:

- surface water chemistry data collected in the field,
- specific types of land use and their locations with respect to the preserve,
- field summaries of the hydrology, geology, geomorphology, and topography at a preserve, and
- an initial evaluation of site vulnerability.

A typical site survey contained the following steps:

1. Drove around the site to determine adjacent land use. Noted land uses on evaluation form (and possibly on the topographic map). Determined a good access point to the preserve.
2. Parked and read through the information in the site folder to identify items of hydrogeologic significance (e.g., presence of shallow aquifers, alterations such as drainage or damming, etc.).
3. Entered the preserve on foot and located a ground-water discharge or surface-water feature and measured basic chemical parameters.
4. Took pictures for reference of noteworthy items (e.g., discharging water, subdivisions, dumping and other obvious pollution, etc.).
5. Returned to vehicle and completed the evaluation form.

The evaluation process evolved as critical issues were identified through field activities. For example, a seven category system was developed for evaluating ground-water vulnerability after the first group of sites were visited. It was also decided to take surface-water chemistry readings when possible. The gathering of the chemistry data forced the field team to walk on site and helped develop a conceptual understanding of the hydrology. A main study goal was to determine the vulnerability of preserves to ground-water contamination. However, since relationships between surface and ground water are often complex at these sites, it was evident early in the study that surface-water conditions should also be evaluated. Indeed, the transitions of surface water to ground water and ground water to surface water create unique chemical environments. If viewed from a mass balance perspective, surface water can be a significant input with potential to greatly affect the ground-water chemistry.

In general, the ground-water evaluations were made by describing potential contaminant sources, assessing the hydrogeologic connection between ground-water discharge features and the land surface, and then ranking the sites. Classifying the ground-water vulnerability of a site was easier and more consistent when the field crews asked themselves three main questions;

1. *Is the geology sensitive?*
   Areas where permeable geologic materials are present at or near the surface are more likely to transmit water rapidly, and therefore are more sensitive to contamination. Sensitivity determinations were largely based on information about nearby domestic wells. Higher rankings were given to sites that had near-surface sands and gravels or karstified limestone. Sites that had sensitive geology were generally classified as having moderate vulnerability or greater.

2. *Are there potential sources of contamination?*
   The closer that potential contamination sources were to the site, the higher the site was ranked. This question required field crews to interpret the relative contamination potential of many sources. Specific attention was paid to several potential sources including agricultural, commercial, industrial, municipal, recreational, residential, and transportational land uses. Sites that fell into categories of higher vulnerability had a relatively large number of potentially contaminating land uses that were adjacent to the preserve.

3. *Are the potential sources upgradient from the site?*
   Obviously, sources that are upgradient are more of a concern than those that are downgradient. An estimate of ground-water flow directions was made based on local topography and available information from well records. In a few cases, hydrogeologic reports were also available for this interpretation.

Seven categories (Figure 7) were used to evaluate the ground-water vulnerability of the sites. These categories take into account the above questions. Categorization was straightforward except at a few sites. It was usually more difficult to classify large preserves (e.g., Goose Lake Prairie) because of greater variation in geology and more complex relationships with adjacent land use. In

Figure 7. Ground-water vulnerability categories used to evaluate selected Illinois nature preserves and immediate surroundings

Very Low - Geology usually is not sensitive* (e.g., no karst or sand and gravel/bedrock aquifers within 50 feet of surface) and the preserve is far (e.g., >2 miles) from potential contaminant sources.

Low - Geology usually is not sensitive*. Surrounding the Preserve (to a distance of - 1 mile) may be some minimal residential and/or agricultural land (e.g., row crops with possible agrichemical application) which are generally in a down gradient position. Sites in areas of sensitive geology may have upgradient agricultural land, however, the sites are well buffered. There are no commercial establishments, industrial facilities, large livestock operations, dump sites, or other potential contaminant sources surrounding the site.

Low to Moderate - Geology usually is not sensitive*. There is no perceived threat. Because of fine-grained surficial materials, potential transfer of chemicals from surface to subsurface is not expected to be rapid. Agricultural land may border the preserve and be upgradient. Sites in areas of sensitive geology also may have upgradient agricultural or residential land, however, the potential impact on the site is expected to be minimal. There may be some commercial establishments, however no industrial facilities, large livestock operations, or dump sites surround the site.

Moderate - Geology is usually sensitive. There may be a perceived threat from agricultural or other land uses which may border or even surround the preserve. Commercial establishments may be present, however, industrial facilities, large livestock operations, or dump sites are not. Paved highways, railroad tracks, or other potential contaminant sources may be present bordering the site.

Moderate to High - Geology is sensitive. Karst or surficial sand and gravel could bring contaminants to the nature preserve from relatively long distances. Some residential, commercial, or industrial development may be present. Agricultural land, highways, railroad tracks, or other potential contaminant sources may be present bordering and upgradient of the site.

High - Geology is sensitive and obvious potential contaminant sources (dump sites, dense residential, commercial establishments, industrial development are present and upgradient). Sources may be on site, but direct impact is not readily identifiable.

Very High - same as high except that obvious sources exist on site and/or direct impact was seen.

*Geology within the preserve (on-site) and outside of the preserve (off-site) may differ. If off-site geology is not sensitive, on-site geology may be sensitive or vice versa.

such cases, a category was chosen that was most representative of the site as a whole. If any areas within the site were expected to have a different vulnerability, they were noted as exceptions on the evaluation forms. Situations also occurred where, for example, dense residential development surrounded a preserve and the geology was judged as not sensitive or moderately sensitive. It was then at the field crew's discretion to place the site in a category ranging from low-moderate to moderate-high based on comparison with other sites that they had visited.

Often, the geology of a preserve and the surrounding area were different. This was especially true where the preserve was in a low-lying area and uplands surrounded it. The most frequent case was where the geology of a preserve was interpreted as sensitive, but the surrounding area was not sensitive (e.g., Spring Bluff Fen). These sites may be classified as having relatively low vulnerability even though potential sources exist near the preserve. In one other case (Pecatonica Bottoms), the geology of a preserve was interpreted as not sensitive, but the surrounding area was sensitive.

Results of Site Surveys

After the site visits were finished, the evaluation forms and site folders were reviewed for completeness. Field personnel clarified and reviewed all field information before it was entered into the electronic database. A subsequent review of the evaluation forms was done to assess the consistency of site characteristics within the ground-water vulnerability categories. Several vulnerabilities were either increased or decreased by one category during this review. This step minimized field crew bias and assured that all sites were categorized similarly.

Because it was difficult to assess on-site impacts due to ground-water contamination, no sites were classified as very highly vulnerable. Impacts could perhaps have been identified by the precipitation of compounds (e.g., iron oxide, manganese oxide, etc.) in areas of ground-water discharge. However, many natural processes also drive precipitation and it was not intended for field crews to address these situations.

A rigorous classification scheme was not developed to evaluate surface-water vulnerability. In some cases, however, a clear distinction was made whether the vulnerability of a site was from surface or ground water. For example, sedimentation from surface water flooding can be detrimental to natural communities in preserves. Preserves that had evidence of sediment deposition from off-site sources were classified as having very high surface-water vulnerability.

Figure 8 and Table 5 show the distribution of site vulnerability based on assembled hydrogeologic information and site surveys. Few sites were categorized as having very low or very high vulnerability to either ground or surface-water contamination. Distribution is relatively even in the low through high surface-water categories. The occurrence of sites in the ground-water categories resembles a normal distribution. For Table 5, the percentage of sites in any one category was calculated separately for ground water and surface water. Sites in the moderate, moderate to high, and high ground-water vulnerability categories account for 60 percent of those evaluated. Similarly, the same categories of surface-water vulnerability account for 54 percent of the sites evaluated. Lists of sites in each of the ground and surface-water categories are given in Figures 9 and 10. A summary of field data for the 85 preserves is listed in Table 6. Complete field information (from which Table 6 was compiled) is archived in the individual site folders.

Figure 8. Distribution of site vulnerability rankings for ground and surface water

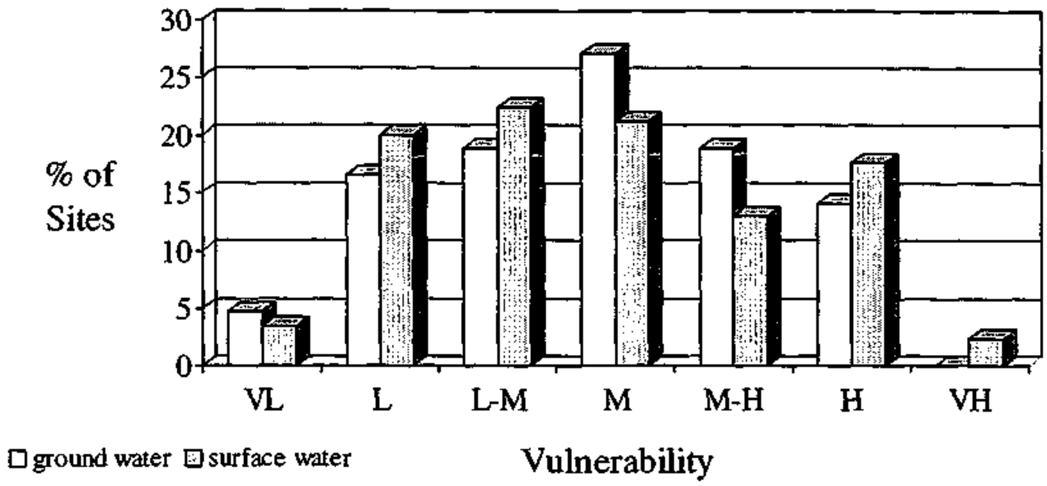


Table 5. Number of sites (and percentage of 85) in each vulnerability category

	Very Low	Low	Low-Moderate	Moderate	Moderate-High	High	Very High
Ground Water[1]	4 (5%)	14 (16%)	16 (19%)	23 (27%)	16(19%)	12 (14%)	0 (0%)
Surface Water	3 (4%)	17 (20%)	19 (22%)	18 (21%)	11(13%)	15 (18%)	2 (2%)

Horseshoe Lake counted as Low-Moderate

Figure 9. Nature preserves in each ground-water vulnerability category

Very Low (4)
- Cranberry Slough
- Cretaceous Hills
- Heron Pond - Little Black Slough
- Miller Shrub Swamp

Low (15)
- Chauncey Marsh
- Hannover Bluff
- Horseshoe Bottom
- Horseshoe Lake (east tract)
- Howard's Hollow Seep
- La Rue Swamp
- Massac Forest
- Mermet Swamp
- Nelson Lake Marsh
- Palos Fen
- Shick Shack Sand Pond
- Skokie River
- Spring Bluff Fen
- Thornton-Lansing Road
- Windfall Prairie

Low to Moderate (15)
- Almond Marsh
- Baker's Lake
- Barrington Bog
- Bennett's Terraqueous Gardens
- Bonnie's Prairie
- Farm Trails North
- Gensburg-Markham Prairie
- Illinois Beach
- Kinnikinnick Creek
- Matanzas Prairie
- North Dunes
- Pecatonica Bottoms
- Pine Rock
- Spring Bay Fen
- Wilkinson-Renwick Marsh

Moderate (24)
- Barber Fen
- Bates Fen
- Calamus Lake
- Cedar Lake Bog
- Churchill Prairie
- Dean Hills
- Elizabeth Lake
- Exner Marsh
- Ferson's Creek
- Franklin Creek

Moderate (continued)
- Glacial Park
- Horseshoe Lake (west tract)
- Kettle Moraine
- Lyon's Prairie and Marsh
- Maramech Woods
- Miller-Anderson Woods
- Momence Wetlands
- Rockton Township Bog
- Section 8 Woods
- Spring Lake
- Tucker-Millington Fen
- Wadsworth Prairie
- Weingart Road Sedge Meadow
- Wolf Road Prairie

Moderate to High (16)
- Armin Krueger Speleological
- Fogelpole Cave
- Forest Glen Seep
- Fox River Fen
- Gavin Bog and Prairie
- Gladstone Fen
- Julia and Royce Parker Fen
- Kishwaukee Fen
- Lake Renwick Heron Rookery
- Lockport Prairie
- Long Run Seep
- Oakwood Hills Fen
- Pistakee Bog
- Turner Lake Fen
- Wauconda Bog
- Wilmington Shrub Prairie

High (12)
- Bluff Springs
- Braidwood Dunes And Savanna
- Cotton Creek Marsh
- George B. Fell
- Goose Lake Prairie
- Lake in the Hills Fen
- Romeoville Prairie
- Sand Ridge
- Searls Park Prairie
- Spring Grove Fen
- Trout Park
- Volo Bog

Very High (0)

Figure 10. Nature preserves in each surface-water vulnerability category

Very Low (3)
- Cretaceous Hills
- Miller Shrub Swamp
- Windfall Prairie

Low (17)
- Braidwood Dunes and Savanna
- Chauncey Marsh
- Cranberry Slough
- Dean Hills
- Forest Glen Seep
- Heron Pond - Little Black Slough
- Horseshoe Bottom
- Horseshoe Lake
- La Rue Swamp
- Momence Wetlands
- North Dunes
- Pine Rock
- Section 8 Woods
- Shick Shack Sand Pond
- Skokie River
- Spring Bluff Fen
- Thornton-Lansing Road

Low to Moderate (19)
- Barber Fen
- Bonnie's Prairie
- Franklin Creek
- Gensburg-Markham Prairie
- Glacial Park
- Gladstone Fen
- Howard's Hollow Seep
- Illinois Beach
- Kinnikinnick Cree
- Matanzas Prairie
- Miller-Anderson Woods
- Nelson Lake Marsh
- Palos Fen
- Pecatonica Bottoms
- Spring Bay Fen
- Spring Lake
- Tucker-Millington Fen
- Turner Lake Fen
- Wadsworth Prairie

Moderate (18)
- Baker's Lake
- Barrington Bog
- Bennett's Terraqueous Gardens
- Calamus Lake

Moderate (continued)
- Churchill Prairie
- Elizabeth Lake
- Exner Marsh
- Ferson's Creek
- Hannover Bluff
- Julia and Royce Parker Fen
- Kettle Moraine
- Long Run Seep
- Mermet Swamp
- Pistakee Bog
- Rockton Township Bog
- Trout Park
- Wilkinson-Renwick Marsh
- Wolf Road Prairie

Moderate to High (11)
- Armin Krueger Speleological
- Bates Fen
- Bluff Springs
- Fogelpole Cave
- Kishwaukee Fen
- Lake Renwick Heron Rookery
- Lockport Prairie
- Maramech Woods
- Massac Forest
- Volo Bog
- Wilmington Shrub Prairie

High (15)
- Cedar Lake Bog
- Cotton Creek Marsh
- Farm Trails North
- Fox River Fen
- Gavin Bog and Prairie
- George B. Fell
- Lake in the Hills Fen
- Lyon's Prairie and Marsh
- Oakwood Hills Fen
- Romeoville Prairie
- Sand Ridge
- Searls Park Prairie
- Spring Grove Fen
- Wauconda Bog
- Weingart Road Sedge Meadow

Very High (2)
- Almond Marsh
- Goose Lake Prairie

Table 6. Summary of ground-water and surface-water vulnerability assessments from site surveys
(listed by overall rating of ground-water vulnerability)

INPC No.	Nature Preserve Name	Ground-Water Vulnerability: Sensitive Geology On-site	Sensitive Geology Off-site	Potential Contaminant Sources	Contam. Sources Up-gradient	Overall Rating	Surface Water Vulnerability: Potential Contaminant Sources	Overall Rating
5	Cranberry Slough	N	N	Well buffered recreational roads	Y	Very low	Minor road runoff	Low
31	Cretaceous Hills	Y	Y	None noted	N	Very low	None noted	Very low
34	Heron Pond - Little Black Slough	N	N	Railroad, minor rural residential development	Y	Very low	Cache River flooding	Low
184	Miller Shrub Swamp	N	N	Buffered agriculture	Y	Very low	None noted	Very low
105	Chauncey Marsh	Y	Y	Residential development, agriculture, distant oil wells	N	Low	Flooding from Crow Branch	Low
150	Hanover Bluff	Y	Y	Agriculture, army depot, heavy residential development	N	Low	High potential for siltation from easement road along powerline	Moderate
70	Horseshoe Bottom	Y	N	Recreational, buffered agriculture	Y	Low	Recreational	Low
199	Howard's Hollow Seep	N	N	Recreational, agriculture, roads	Y	Low	Slope wash	Low-mod
173	La Rue Swamp	Y	Y	Recreational (campground)	Y	Low	Same as ground water	Low
84	Massac Forest	N	N	Rural residential development	Y	Low	Ohio R. flooding, sedimentation	Mod-high
20	Mermet Swamp	N	N	Route 45, railroad	Y	Low	Same as ground water	Moderate
80	Nelson Lake Marsh	N	N	Lawns, agriculture, grazing, recreational development	Y	Low	Residential & agricultural (livestock) runoff	Low-mod
120	Palos Fen	N	N	Lawns, pipeline	Y	Low	Road runoff	Low-mod

Table 6. Summary of ground-water and surface-water vulnerability assessments from site surveys
(listed by overall rating of ground-water vulnerability)

INPC No.	Nature Preserve Name	Ground-Water Vulnerability: Sensitive Geology		Ground-Water Vulnerability: Potential Contaminant Sources	Contam. Sources Up-gradient	Overall Rating	Surface Water Vulnerability: Potential Contaminant Sources	Overall Rating
		On-site	Off-site					
133	Shick Shack Sand Pond	Y	Y	Buffered agriculture	Y	Low	Same as ground water	Low
216	Skokie River	N	N	Railroad, golf course, residential development	Y	Low	Same as ground water	Low
213	Spring Bluff Fen	Y	N	Residential development	Y	Low	Railroad, residential development	Low
12	Thornton-Lansing Road	Y	Y	Lawns, old residential development, well buffered	Y	Low	Ditching, road runoff	Low
72	Windfall Prairie	N	N	Agriculture	Y	Low	None noted	Very low
195	Almond Marsh	N	N	Lawns, septics	Y	Low-mod	Residential development, roads	Very high
119	Baker's Lake	N	N	Residential development, railroad, roads	Y	Low-mod	Residential & road runoff	Moderate
158	Barrington Bog	N	N	Septic, residential development	Y	Low-mod	Rt. 59 runoff	Moderate
190	Bennett's Terraqueous Gardens	Y	N	Residential and commercial development	Y	Low-mod	Runoff from Rt. 116, storm water discharge into site	Moderate
218	Bonnie's Prairie	Y	Y	Agriculture, railroad	Y	Low-mod	Same as ground water	Low-mod
233	Farm Trails North	Y	N	Commercial & residential development, roads, utilities	Y	Low-mod	Road runoff	High
77	Gensburg-Markham Prairie	Y	N	Residential & commercial development, roads	Y	Low-mod	Ditching, minimal runoff	Low-mod

Table 6. Summary of ground-water and surface-water vulnerability assessments from site surveys
(listed by overall rating of ground-water vulnerability)

INPC No.	Nature Preserve Name	Ground-Water Vulnerability					Surface Water Vulnerability	
		Sensitive Geology		Potential Contaminant Sources	Contain. Sources Up-gradient	Overall Rating	Potential Contaminant Sources	Overall Rating
		On-site	Off-site					
19	Horseshoe Lake	Y	Y	Agriculture surrounds western tract, eastern tract is an island	Y	Low-mod	Flooding?	Low
1	Illinois Beach	Y	N	Industrial & recreational development, roads	Y	Low-mod	Same as ground water	Low-mod
53	Kinnikinnick Creek	N	N	Minor residential development, roads, recreational development, agriculture	Y	Low-mod	Flooding	Low-mod
131	Matanzas Prairie	Y	Y	Rural residential development, agriculture	Y	Low-mod	Same as ground water	Low-mod
166	North Dunes	Y	Y	Old development	Y	Low-mod	Flooding?	Low
96	Pecatonica Bottoms	N	Y	Roads, agriculture, livestock, park maintenance facility	Y	Low-mod	Flooding from river, road runoff	Low-mod
16	Pine Rock	Y	Y	Residential development, agriculture, roads	Y	Low-mod	None noted	Low
76	Spring Bay Fen	Y	Y	Residential development, mining	Y	Low-mod	Illinois River flooding	Low-mod
229	Wilkinson-Renwick Marsh	N	N	Agriculture surrounds site, railroad, rural residential development	Y	Low-mod	Railroad, agriculture, tiles	Moderate
198	Barber Fen	Y	Y	Residential development, agriculture, grazing	Y	Moderate	Nippersink Creek flooding	Low-mod
244	Bates Fen	Y	Y	Recreational development, golf course, mining	Y	Moderate	Same as ground water	Mod-high

Table 6. Summary of ground-water and surface-water vulnerability assessments from site surveys
(listed by overall rating of ground-water vulnerability)

INPC No.	Nature Preserve Name	Ground-Water Vulnerability					Surface Water Vulnerability	
		Sensitive Geology		Potential Contaminant Sources	Contain. Sources Up-gradient	Overall Rating	Potential Contaminant Sources	Overall Rating
		On-site	Off-site					
208	Calamus Lake	Y	N	Rural residential development, hog farm, agriculture, old dumping	Y	Moderate	Sangamon River flooding, dumping	Moderate
57	Cedar Lake Bog	N	N	Institutional residences, residential development, dumping	Y	Moderate	Road runoff	High
225	Churchill Prairie	Y	Y	Residential development, railroad, agriculture, underground storage tanks	Y	Moderate	Culverts, road runoff	Moderate
127	Dean Hills	Y	Y	Rural residential development, dumping, tree farm	Y	Moderate	Potential river flooding	Low
128	Elizabeth Lake	Y	Y	Residential & recreational development, dumping	Y	Moderate	Same as ground water plus road runoff	Moderate
235	Exner Marsh	N	N	Residential developments, agriculture, roads	Y	Moderate	Road runoff, residential development, agriculture	Moderate
196	Ferson's Creek Fen	Y	Y	Residential development	Y	Moderate	Rt. 31 runoff, Ferson Creek & Fox River flooding	Moderate
24	Franklin Creek	Y	Y	Residential development, agriculture, dumping	Y	Moderate	Agriculture	Low-mod
214	Glacial Park	Y	Y	Lawns, wells, stables, agriculture	Y	Moderate	Same as ground water	Low-mod
51	Kettle Moraine	Y	Y	Residential & recreational development, mining, pipeline	Y	Moderate	Same as ground water	Moderate

Table 6. Summary of ground-water and surface-water vulnerability assessments from site surveys
(listed by overall rating of ground-water vulnerability)

INPC No.	Nature Preserve Name	Ground-Water Vulnerability					Surface Water Vulnerability	
		Sensitive Geology		Potential Contaminant Sources	Contain. Sources Up-gradient	Overall Rating	Potential Contaminant Sources	Overall Rating
		On-site	Off-site					
91	Lyon's Prairie & Marsh	Y	Y	Roads, agriculture, recreational development	Y	Moderate	Sedimentation, ditches, roads	High
155	Maramech Woods	N	N	Minor residential development, pasture, grazing, agriculture, roads	Y	Moderate	Road runoff	Mod-high
23	Miller-Anderson Woods	N	N	On-site dumping, on-site pipeline, agriculture, residential development	Y	Moderate	Road runoff from Route 29	Low-mod
165	Momence Wetlands	Y	Y	Oil pipeline on-site, old debris on-site, agriculture, residential development	Y	Moderate	Kankakee River flooding	Low
36	Rockton Township Bog	Y	Y	Lawns, septic, dumping, agriculture, grazing, roads, sewage sludge	Y	Moderate	Siltation, road runoff	Moderate
186	Section 8 Woods	Y	Y	Agriculture, roads, railroad	Y	Moderate	Road runoff, Cache R. flooding	Low
11	Spring Lake	Y	Y	Residential development, roads, grazing	Y	Moderate	Road runoff	Low-mod
212	Tucker-Millington Fen	Y	Y	Minimal nearby residential development with septic, grazing, railroad, dumping	Y	Moderate	Railroad, road runoff	Low-mod
83	Wadsworth Prairie	Y	Y	Railroad, commercial development	Y	Moderate	Highway, commercial development	Low-mod
129	Weingart Road Sedge Meadow	N	N	Residential & recreational development, dumping, roads	Y	Moderate	Flooding	High

Table 6. Summary of ground-water and surface-water vulnerability assessments from site surveys
(listed by overall rating of ground-water vulnerability)

INPC No.	Nature Preserve Name	Ground-Water Vulnerability					Surface Water Vulnerability	
		Sensitive Geology		Potential Contaminant Sources	Contam. Sources Up-gradient	Overall Rating	Potential Contaminant Sources	Overall Rating
		On-site	Off-site					
164	Wolf Road Prairie	N	N	Residential & recreational development, landfill, roads	Y	Moderate	31st St. & Wolf Rd. runoff	Moderate
189	Armin Krueger Speleological	Y	Y	Agricultural fields surround the site	Y	Mod-high	Same as ground water	Mod-high
177	Fogelpole Cave	Y	Y	Rural residential development, agriculture surrounds site	Y	Mod-high	Same as ground water	Mod-high
113	Forest Glen Seep	Y	Y	Abandoned sand & gravel pits, grazing, agriculture	Y	Mod-high	Flooding from creek	Low
209	Fox River Fen	Y	Y	Railroad, recreational development, road	Y	Mod-high	Road runoff	High
88	Gavin Bog and Prairie	Y	Y	Residential development, dumping	Y	Mod-high	Storm water discharge pipe	High
204	Gladstone Fen	Y	Y	Agriculture, mining, future residential development	Y	Mod-high	Same as ground water	Low-mod
135	Julia M. and Royce L. Parker Fen	Y	Y	Residential development, agriculture	Y	Mod-high	Same as ground water	Moderate
223	Kishwaukee Fen	Y	Y	Agriculture, golf course	Y	Mod-high	Same as ground water	Mod-high
217	Lake Renwick Heron Rookery	Y	Y	Old & current mining, cemetery	Y	Mod-high	Rt. 30 runoff, culverts	Mod-high
110	Lockport Prairie	Y	Y	Mining, agriculture, roads, dumping	Y	Mod-high	Flooding, road runoff	Mod-high

Table 6. Summary of ground-water and surface-water vulnerability assessments from site surveys
(listed by overall rating of ground-water vulnerability)

INPC No.	Nature Preserve Name	**Ground-Water Vulnerability**					Surface **Water Vulnerability**	
		Sensitive Geology		**Potential Contaminant** Sources	Contam. Sources Up-gradient	**Overall Rating**	**Potential Contaminant** Sources	**Overall Rating**
		On-site	Off-site					
188	Long Run Seep	Y	Y	Industrial & residential development, septic	Y	Mod-high	Flooding, runoff, upstream development	Moderate
138	Oakwood Hills Fen	Y	Y	Commercial, residential, & recreational developments	Y	Mod-high	Flooding from Silver Creek	High
56	Pistakee Bog	Y	Y	Stables, agriculture, mining	Y	Mod-high	Same as ground water	Moderate
167	Turner Lake Fen	Y	Y	Lawns, wells, residential development	Y	Mod-high	Same as ground water	Low-mod
26	Wauconda Bog	Y	Y	Lawns, septics	Y	Mod-high	Culverts and roads	High
181	Wilmington Shrub Prairie	Y	Y	Mining, agriculture, minor dumping, recreational development, pipeline	Y	Mod-high	Ditching, road runoff	Mod-high
146	Bluff Springs Fen	Y	Y	Lawns, roads, cemetery, landfill, mining	Y	High	Road runoff, culverts	Mod-high
81	Braidwood Dunes and Savanna	Y	Y	Residential development, mining, pipeline, grazing	Y	High	No distinct inputs	Low
98	Cotton Creek Marsh	Y	Y	Lawns, sewage line, feedlots, roads, dumping, storage tanks?	Y	High	Route 176 and residential roads	High
43	George B. Fell	Y	Y	Mining, agriculture, residential development, road, dumping	Y	High	Runoff from stables?	High
21	Goose Lake Prairie	Y	Y	Commercial & industrial development, mining, agriculture, railroad	Y	High	Acidic mine drainage on-site	Very high

Table 6. Summary of ground-water and surface-water vulnerability assessments from site surveys
(listed by overall rating of ground-water vulnerability)

INPC No.	Nature Preserve Name	Ground-Water Vulnerability					Surface Water Vulnerability	
		Sensitive Geology		Potential Contaminant Sources	Contam. Sources Up-gradient	Overall Rating	Potential Contaminant Sources	Overall Rating
		On-site	Off-site					
185	Lake-in-the-Hills Fen	Y	Y	Industrial, commercial, residential, & recreational developments, mining, agriculture	Y	High	Road runoff as well as ground water sources	High
126	Romeoville Prairie	Y	Y	Industrial development, lawns, sewage treatment, cemetery, landfill, dumping	Y	High	Runoff from industrial park	High
9	Sand Ridge	Y	Y	Commercial development, lawns, sewers, roads, pipeline	Y	High	Major runoff	High
117	Searls Park Prairie	Y	Y	Junkyard, bodyshop, roads, agriculture	Y	High	Runoff from businesses to east	High
168	Spring Grove Fen	Y	Y	Septic, railroad, golf course, roads, mining	Y	High	Same as ground water, culverts under RR, flooding	High
42	Trout Park	Y	Y	Residential & recreational development, pipelines	Y	High	Runoff from I-90 and other busy roads	Moderate
25	Volo Bog	Y	Y	Industrial & residential development, agriculture, golf course	Y	High	Same as ground water	Mod-high

Database Preparation

An electronic database was developed using dBASE (version 5.0) software. It contains field survey data from the 85 sites and was created for several reasons. First, while it would be impractical to reproduce all of the field data gathered throughout the project, it does allow for storage of pertinent information (e.g., data entered on the field evaluation forms) in a compact and easily duplicated format. It is intended that this information will be added or referenced to the existing database(s) of site information maintained by the INPC. A complete printout of the information contained in the database is presented in Volume EL Second, the information in the database is readily retrievable. As with many database programs, dBASE has numerous ways to search for information (e.g., for keywords, dates, designated numerical values, etc.). An example of one such use would be where the database is queried to return a list of all the surveyed preserves that had residential septic systems nearby. While these types of searches are constrained to the features explicitly identified during the site surveys (see field evaluation form in Appendix C), this could be very helpful in identifying preserves with similar characteristics. Third, it makes addition of other preserves to the database possible.

Regional Sensitivity vs. Local Vulnerability

Classifications were made at 85 sites identifying both their regional sensitivity and local vulnerability. These classifications are related, but are not interchangeable. During vulnerability assessments well records were reviewed to determine local geologic sensitivity. Regional sensitivity was determined separately and was not a factor in local vulnerability assessments.

Sites that are classified in higher vulnerability categories (see Appendix A) tend to have higher regional sensitivities. Cases do exist where either sites with low regional sensitivity have high vulnerability or sites with high regional sensitivity have low vulnerability. The primary difference between these classifications is land use. Because of the criteria used and the scale which assessments were made, local vulnerability assessments take precedence over regional sensitivity classifications.

SITE CHARACTERIZATION AND MONITORING

A study site was chosen for a detailed geologic and hydrologic characterization from six potential preserves. Field personnel, who conducted the site surveys, visited Gensburg-Markham Prairie, Lake-in-the-Hills Fen, Exner Marsh, Bates Fen, Spring Grove Fen, and Turner Lake. Even though site surveys had not yet been conducted, site data assembled for the surveys was used during these preliminary visits. Spring Grove Fen Nature Preserve (Figure 11) was selected for a detailed study because of it's expected high vulnerability, accessibility, and size. The preserve was dedicated to the INPS on September 29, 1988 and covers 33.4 acres just east of the village of Spring Grove in Section 30, T46N, R9E, McHenry County, Illinois. Within the nature preserve, the state endangered purple-flowering raspberry and the state threatened bog bedstraw are present.

Once Spring Grove Fen was selected, additional available data was collected. For example, land-use maps (1:9600 scale) for Richmond and Burton Townships and reproductions of aerial photographs (1:2400 scale) over the study area were obtained from the McHenry County Planning Office. In addition, digital scans and enlarged pictures of the study area were made from aerial photographs taken during 1939, 1954, and 1967. These and other aerial coverages for the state are housed at the University of Illinois Map and Geography Library. More recent aerial photographs have been taken in McHenry County and were available on CD-ROM as digital orthophoto quadrangles.

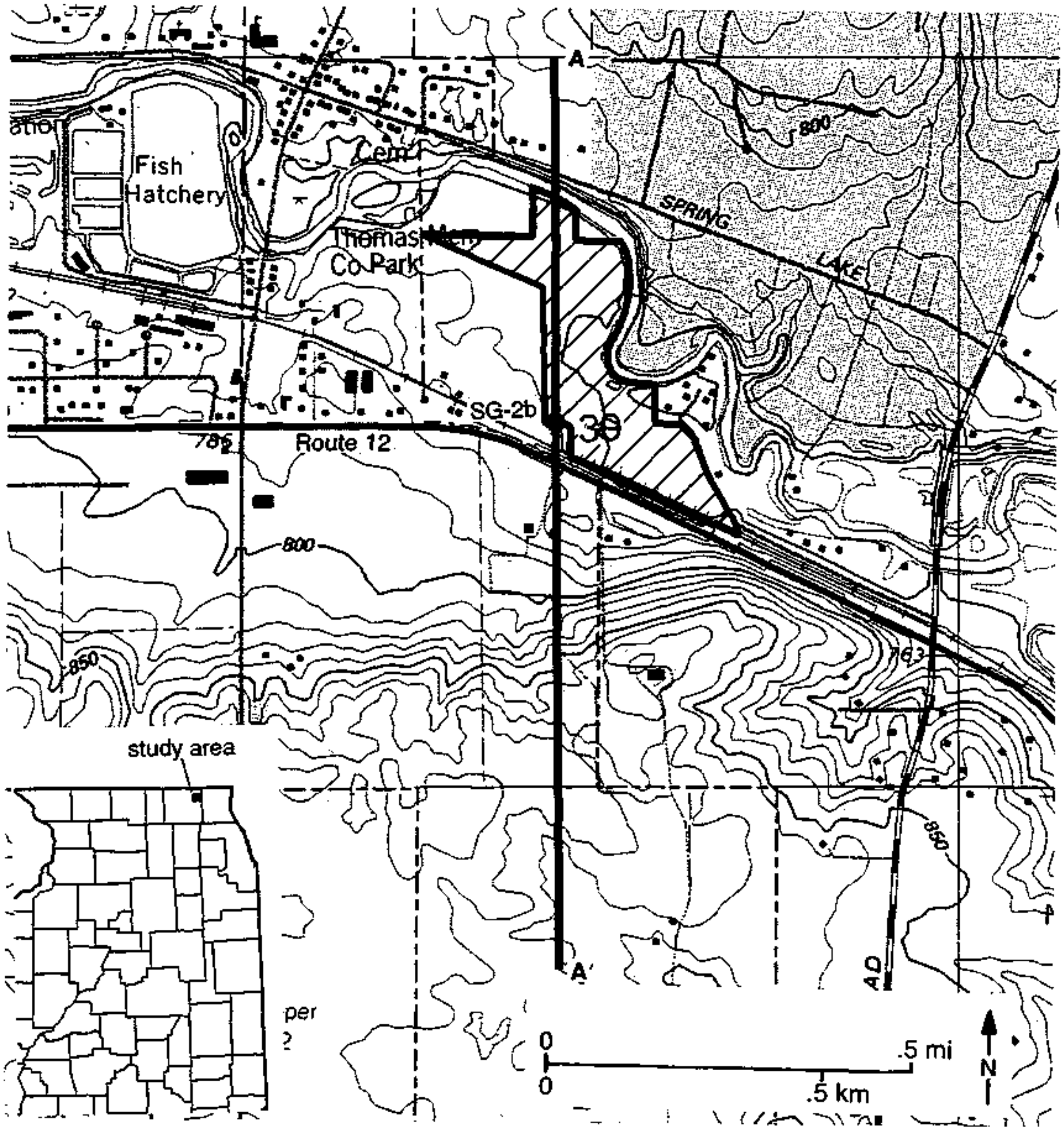
A detailed characterization of the site hydrology and geology was conducted between June 1995 and October 1996. A Category HI Quality Assurance Project Plan (QAPP) was developed prior to detailed field work (ISWS, 1995 unpublished). It identified 1) specific measurements to be made in the field and lab, 2) all methods of analysis to be used, 3) field procedures for well installation, development, and sampling, and 4) how chemical data would be assessed for accuracy and precision. Category HI projects are defined by the U.S. EPA (Simes, 1991) as "those producing results for the purpose of evaluating and selecting basic options, or performing feasibility studies or preliminary assessments of unexplored areas which might lead to further work." Data gathered during this study should be readily comparable with future data collected at Spring Grove Fen. It was for this reason, as well as, improving overall data quality, that all aspects of data collection and analysis were documented. Methods described in the QAPP are summarized in this report where necessary and quality assurance data are presented later.

Summary of Field and Lab Methods

Drilling and Monitoring Well Construction

While data collected for the site surveys was valuable, the collection of site-specific hydrogeologic information is crucial to better understand, manage, and protect nature preserves. To

Figure 11. Location of Spring Grove Fen Nature Preserve and cross section A-A'

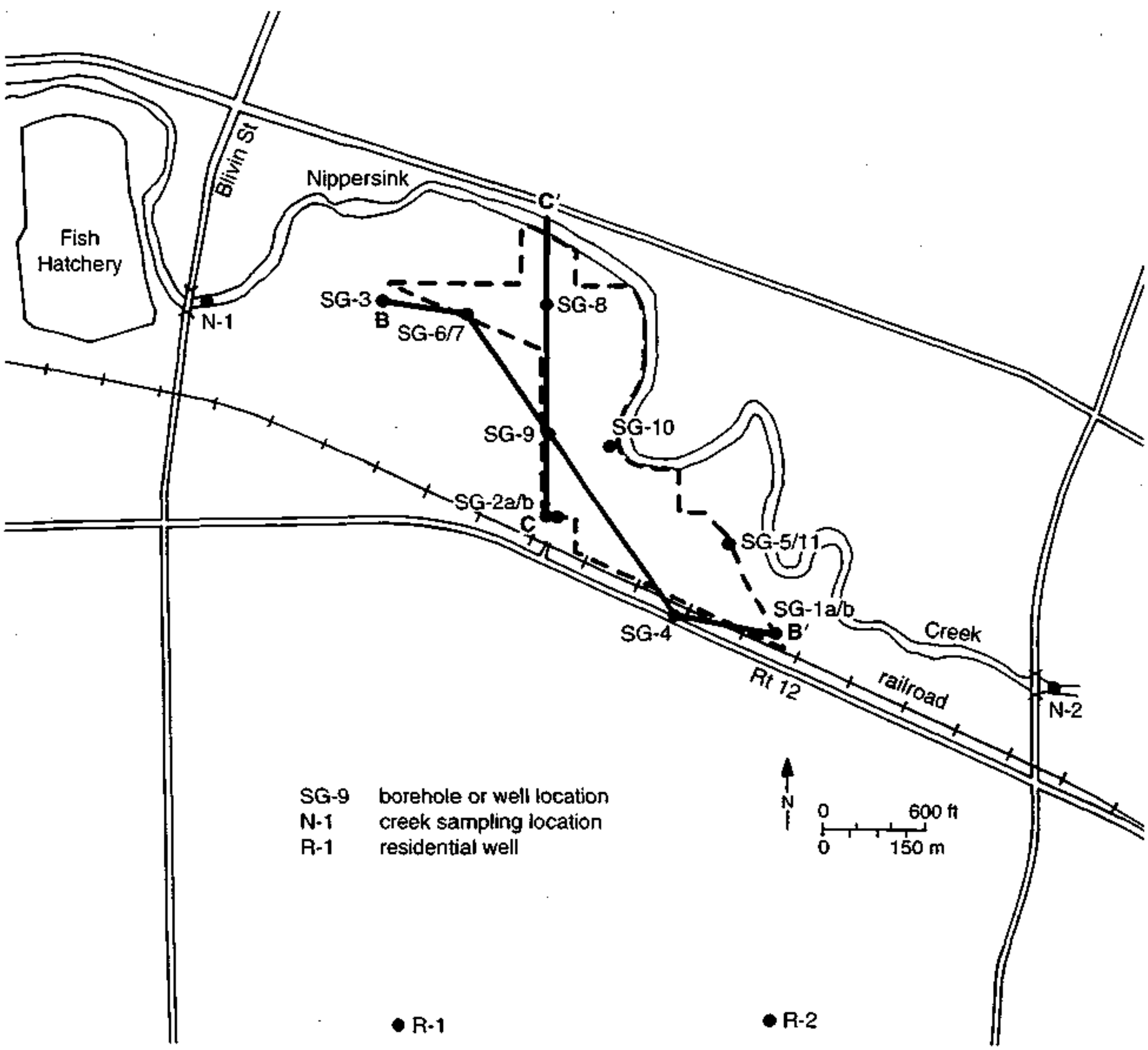


further investigate the local hydrogeology of Spring Grove Fen, a drilling program was conducted to provide very detailed and reliable geologic information and to construct ground-water sampling points. Monitoring installations (observation wells and drive points), henceforth called wells, were constructed within the study area and were used to gather water-quality samples and water-level data. Since this involved work within the preserve boundary, annual special use permits were obtained from the INPC for 1995 and 1996. Several methods of test drilling and well installation were utilized at the locations shown in Figure 12. A location number (e.g., SG-la) is used to identify a borehole location and, if constructed, a corresponding well. In some cases, (SG-3, 7, and 11) wells were not installed once the borehole was constructed. Locations are also noted where the water level measurements and water quality samples were taken from Nippersink Creek (N-l and N-2) and residential wells (R-l and R-2). In general, methods described in ASTM D 5092 (1994a) were used as a basis for well construction and development. Stratigraphic sampling was based on ASTM methods D 1452 (1994b), D 1586 (1994c), and D 1587 (1994d).

At four locations (SG-lb, 2b, 3, and 4), hollow stem augering was done between July 17, 1995 and July 21, 1995 using the ISWS Mobile Drill™B-57 drill rig. The depth of these borings were 7.3, 10.4, 12.0, and 13.8m (24.0, 34.0, 39.5, and 45.3 ft), respectively. Shallower borings were also made at two locations (SG-la and SG-2a) in order to install observation wells to allow measurement of vertical hydraulic gradients. These borings went 4.1 and 3.0 m (13.3 and 10.0 ft.), respectively. Detailed descriptions of the geologic materials encountered in all six boreholes were made (Appendix D) and are described later. Observation wells were constructed in five of the boreholes (SG-la, lb, 2a, 2b, and 4) with polyvinyl chloride (PVC) flush threaded, 5 cm (2 in.) diameter, Schedule 40 materials. A summary of well specifications for those and other wells used at Spring Grove Fen are shown in Appendix E.

During the drilling of these wells, water from the Spring Grove Fire Department was used as a drilling fluid to flush material out of the borehole. While a well record was not available, the depth of this well is estimated at 52 m (170 ft) from discussion with Fire Department personnel. Water from this well is expected to be similar in chemistry to water from the residential wells. While the water smelled sulfurous, a chemical analysis was not done. No other drilling fluids were used. The first round of water samples was taken three weeks after drilling and well development was completed. Alteration of the natural water chemistry probably occurred because of the introduction of non-native water during drilling. Since no consistent chemical changes were seen in the wells (SG-la/b, 2a/b, and 4) for any one analyte during the first and second quarters, chemical effects of the non-native water on the first round of sampling are expected to be minimal. Estimates were made of the average ground-water velocity in the vicinity of these wells using hydraulic gradients described later. Using a conservative estimate of 60 cm/day (~ 2 ft/day) and assuming that four cubic meters of drilling water (~1000 gallons) was injected into the borehole, the non-native water still had a significant amount of time to migrate away from the well before sampling took place.

Figure 12. Location of sampling points and cross sections B-B' and C-C'



An effort was made to set the screened intervals of the wells in the upper portion of the surficial sand (Cahokia or Henry Formation). In general, a filter or sand pack was added on top of the natural collapse to separate the well screen from the annular seal of bentonite. Bentonite was added on top of the sand pack and filled the annular space almost to the land surface. The annular space was then topped with fine-grained materials which came from the borehole. During the same week as drilling, wells were developed by air lifting. This was done by surging compressed air into the well until the silt and clay content in the well discharge was not visible and most of the fine sand content had significantly decreased. While turbidity was not measured, most wells produced very clear water after they were developed.

Observation wells were also constructed at two locations (SG-5 and SG-6) by driving pre-contracted 3.2 cm (1.25 in) diameter 304 stainless steel wells in place with a sliding hammer. These wells had a 30 cm (1.0 ft) continuous slot screen. Because the screen had a slightly larger diameter than the drive point, a small annular space was created during installation of the wells. This was filled with granular bentonite and was covered with native materials to reduce the amount of surface infiltration at the well. No gravel was encountered at either of these locations, however, a loosely cemented very friable sand was encountered while driving SG-5. This layer was also encountered in hand borings taken between SG-6 and SG-3. The finer-grained material near the surface at SG-6 made it very difficult to drive, therefore, the screened interval was set relatively shallow.

In other relatively inaccessible locations (SG-7 through SG-11), four-inch diameter boreholes were drilled to depths less than 4.6 m (15 ft) feet by hand with an Eijkelkamp Hollow-Stem Kit. Boreholes SG-7 and SG-11 were used to identify the materials present at SG-5 and SG-6. Observation wells with 76 cm (2.5 ft.) screens were constructed of PVC materials in the other three boreholes (SG-8, 9, and 10). The screens of these wells were set in sandy materials located below the surficial peat. Sand packs were made around the screens by a combination of natural collapse and addition of filter sand. Granular and pelletized bentonite were used to seal the annular space to near the land surface and then native materials were used as a cover. The water levels in these wells were measured at the same time that other wells in the network were measured and sampled. The primary function of these wells was to increase the density of water level measurement points, especially near Nippersink Creek.

Surveying

After wells were constructed, well locations were surveyed using Leica System 200 Global Positioning System (GPS) units. Where locations could not be surveyed directly by GPS, standard optical surveying techniques were also used. The System 200 GPS units are high accuracy, dual-frequency, nine-channel GPS receivers which are reported to produce a surveying accuracy of +/-10 mm + 1ppm in the horizontal direction (Leica, 1993). Vertical accuracy is typically two times that of the horizontal.

A high quality National Geodetic Survey benchmark (Nipper 1935; permanent ID # NH1055) located within one mile of Spring Grove Fen was used as a reference for all surveying activities. Assuming that the reported value for Nipper is correct, surveyed locations are expected to have an accuracy of +/- 4 cm in the vertical direction and +/- 3 cm in the horizontal direction. Both static and real-time kinematic GPS surveying techniques were used. Well SG-6 was surveyed by both static and real-time kinematic methods. Use of high accuracy GPS was necessary to determine the well locations accurately enough to detect shallow ground-water gradients both in the horizontal and vertical directions. It was also very helpful to: 1) locate points within the preserve that were difficult to reach and 2) minimize movement within the preserve because of potential damage to sensitive species. As has been found in previous high accuracy GPS surveys at the ISWS, significant effort is required to properly plan field activities and process satellite data.

Water Sampling and Analysis

Two residential wells, seven observation wells, and one borehole were used to collect ground-water chemistry data. Samples were also taken at two locations from Nippersink Creek. In total, sixty-four sample sets (including trip blanks and field duplicates) were collected from both ground and surface water sampling locations between 8/95 and 10/96. Samples were taken approximately quarterly during 8/95, 1/96, 4/96, 8/96 and 10/96. Analyses of these samples: 1) identified the present quality of ground water at Spring Grove Fen Nature Preserve and 2) provide a baseline to better assess any potential future impacts development may have on the nature preserve.

A list of anticipated chemical measurements in the field and laboratory was developed for the QAPP. That list was revised to include measurements that were added and deleted throughout the project (Table 7). Several herbicide and herbicide metabolite measurements were added to clarify ambiguous sampling results from previous quarters. For example, Millipore EnviroGard™ immunoassay kits were the primary screening tool used to identify the presence of alachlor, triazine, and 2,4-D residues during the first quarter. Six samples showed concentrations of alachlor residues. Since positive detections by the kits could have been produced by one or several cross reacting compounds, gas chromatography (GC) analysis of alachlor and atrazine was done in subsequent quarters. Samples that tested positive by immunoassay were then analyzed by GC for the parent herbicide compounds of atrazine and alachlor, but not 2,4-D.

GC was also used to scan for 59 volatile organic compounds (VOCs) during the first quarter and third quarters (see Appendix F). While no detections of VOCs were expected, the collection of such data was important to document that those compounds were not present.

Table 7. Analytes, Minimum Concentrations of Concern, Method Detection Limits, US EPA methods, ASTM methods, and detected range (All units in mg/L except as noted)

Analyte	(1)	MCC (1)	MDL (2) (2)	US EPA Method Used	**Detected** Range Above MDL
Dissolved Anions	*Anions*			300.0	
Chloride, Cl	Cl	5	0.3		**2.6-121.0**
Fluoride, F		1	0.1		0.1-0.8
Nitrate, NO_3	NO_3	1	0.1		0.1-6.7
Nitrite **(3),** NO_2	NO_2	1	**0.05**		
Sulfate, SO_4	SO_4	5	0.9		**36.0-95.1**
*Dissolved **Cations/Metals***				200.7	
Aluminum, **Al**		1	0.0**29**		not detected
Antimony, **Sb**		5	0.68		not detected
Arsenic, **As**		2	0.24 (4)		not detected
Barium, Ba		1	0.**003**		0.023-0.119
Beryllium, Be		1	0.**003**		**0.012**
Bismuth **(3), Bi**		2	**0.16**		
Boron, **B**		1	0.05		0.05-0.09
Cadmium, **Cd**		1	0.01 **(4)**		**0.01**
Calcium, Ca **(393.3 nm)**		1	0.07		64.73-114.31
Chromium, **Cr**		1	0.015 (4)		not detected
Cobalt, Co		1	0.018		**0.020**
Copper, **Cu**		1	0.**007**		0.008-0.045
Iron, **Fe**		1	0.**007**		0.005-1.958
Lead, Pb		1	0.**089**		not detected
Lithium, **Li**		1	0.**006**		0.006-0.010
Magnesium, Mg (383.2 nm)		1	0.03		35.71-56.85
Manganese, **Mn**		1	0.**002**		0.003-2.214
Mercury, **Hg**		1	0.06 (4)		not detected
Molybdenum, Mo		1	0.031		not detected
Nickel, **Ni**		1	0.**042**		not detected.
Phosphorus, P		5	0.52		not detected
Potassium, K		5	1.29		**1.4-2.2**
Selenium, **Se**		2	0.36 (4)		not detected
Silicon, **Si**		1	0.03		2.67-11.36
Silver, Ag		1	0.**007**		not detected
Sodium, Na (588.9 nm)		1	0.08		2.95-51.82
Strontium, **Sr**		1	0.**003**		0.064-0.195
Sulfur, S		5	0.26		**11.1-32.6**
Thallium, **Tl**		5	0.4		not detected
Tin, **Sn**		1	0.06		not detected
Titanium, Ti		1	0.**003**		not detected
Vanadium, V		1	0.012		not detected
Zinc, **Zn**		1	0.**006**		0.006-0.620

(1) Minimum Concentration of Concern
(2) Method Detection Limit
(3) Measurement Deleted
(4) MCC and MDL are above the maximum contaminant level
(5) Measurement added
(6) See Appendix F

Table 7. (cont.) Analytes, Minimum Concentrations of Concern, Method Detection Limits, US EPA methods, ASTM methods, and detected range (All units in mg/L except as noted)

Analyte	MCC (1)	MDL (2)	US EPA Method Used	Detection Range Above MDL
Nutrients				
Ammonium, NH_4	0.5	0.02	350.1	0.02 - 0.21
Non-Volatile Organic Carbon	2	0.2	415.2	0.5 - 11.1
Total Kjeldahl Nitrogen, TKN	0.5	0.02	351.1	0.1 - 2.2
Pesticides by Immunoassay, (µg/L)				
2,4-D Residues (5)	5	0.5		0.5 - 0.7
Alachlor Residues	5	0.1		0.1 - 1.0
Triazine Residues	5	0.1		0.2 - 0.9
Pesticides by Gas Chromatography (5), (µg/L)				
Alachlor	5	0.4	507	not detected
Atrazine	5	0.1		0.1 - 0.5
Diazinon	5	0.007		0.090 - 0.010
Prometon	5	0.1		not detected
Simazine	5	0.1		0.2
Pesticide Metabolites by Immunoassay (5), (µg/L)				
Alachlor ESA		0.1		0.22 - 1.29
Pesticide Metabolites by High Pressure Liquid Chromatography (5), (µg/L)				
Acetochlor OXA		0.2		not detected
Acetochlor ESA		0.2		not detected
Alachlor OXA		0.2		not detected
Alachlor ESA		0.2		0.27 - 1.03
Hydroxy-Atrazine		0.2		not detected
Metolachlor OXA		0.2		0.64
Metolachlor ESA		0.2		0.23 - 2.57
VOC Scan				
59 compounds (6), (µg/L)	2	<0.21	502.2	not detected
Physical/Chemical Properties				
Lab Parameters				
Total Alkalinity (as $CaCO_3$)	10	1	310.1	245 - 439
Total Dissolved Solids (105° C)	10	1	160.1	354 - 736

Other Physical/Chemical Properties

Parameter	Desired Accuracy	Equipment Accuracy	US EPA Method Used	ASTM Method Used	Detected Range
Lab					
pH (units)	± 0.05	± 0.03	150.1		7.27 - 8.43
Field					
Dissolved Oxygen (3), (mg/L)	± 5%	± 1%		D888	
Eh (5), (mV)	± 5	± 1			-82 - 367
pH (units)	± 0.05	± 0.03		D1293	6.70 - 8.56
Specific Conductance (µS/cm)	± 5	± 1		D1125	465 - 800
Temperature (° C)	± 0.1	± 0.1			15.5 - 26.2

(1) Minimum Concentration of Concern
(2) Method Detection Limit
(3) Measurement Deleted
(4) MCC and MDL are above the maximum contaminant level
(5) Measurement added
(6) See Appendix F

Methods described in ASTM D 4448 (1994e) were used as a basis for well sampling. Most water levels were within suction lift capabilities (~7.6 m), and a peristaltic pump was used for retrieving samples. At residential wells, samples were taken from an outside spigot near the well. Materials entering the well (i.e., sampling equipment) were made from Teflon, stainless steel, or Tygon. Sampling equipment that was placed into a well was thoroughly rinsed with deionized water prior to placement in another well. At least three liters of deionized water was pumped through all pumping mechanisms and tubing prior to use at the next sampling location. In addition, a flow-through cell was used during well purging to determine when a representative ground-water sample could be collected. The following instruments were routinely used during sampling:

Orion Model SA 250 meter with Ross Sure-Flow pH electrode (model 81-65)
Orion automatic temperature compensation probe (catalog number 917001)
Beckman RC-16C conductivity bridge
Orion Model SA 250 meter with Orion redox electrode (model 97-78)

These probes were calibrated at the beginning of each day and periodically checked with standard solutions. Minor calibration adjustments were made as necessary and few problems were encountered with the instruments. During the first quarter, the conductivity bridge was not functioning and no conductivity data was recorded in the field.

The following general procedure was used at each sampling point:

1) Measured and recorded depth to water from surveyed mark.
2) Set up peristaltic pump (if necessary) and flow-through cell.
3) Began pumping and recorded time of start. Adjusted flow rate to ~500 mL/minute.
4) Using the probes in the flow-through cell, monitored pH, conductivity, temperature, and Eh.
5) Began sampling once probe readings stabilized for five minutes for pH (± 0.05 units), conductivity (± 5 µ S/cm), and temperature (± 0.1° C). Recorded stabilized values. A stable Eh reading was not required.
6) Adjusted valve to divert water around the flow-through cell. Collected unfiltered water samples for:
    a) VOC (2 - 40 mL amber glass bottles)
    b) NVOC (2 - 125 mL amber glass bottles)
    c) herbicide scan (2 - 40 mL amber glass bottles)
    d) pH and alkalinity (1 - 60 mL HDPE bottle)
    e) ammonia-N and total Kjeldahl N (1 - 500 mL HDPE bottle)
7) Took unfiltered duplicate samples as needed.
8) Attached either an in-line filter or filter plate (with 0.45 µ m filter) to the pump discharge and flushed with at least 100 mL of water.
9) Took filtered samples for:
    a) dissolved anions and TDS (1-500 mL HDPE bottle),
    b) dissolved metals (1-500 mL HDPE bottle).
10) Took filtered duplicate samples as needed.

11) Added preservative as needed and chilled samples with ice to approximately 4° C immediately after collection.
12) Flushed the sample tubing with at least 3 liters of deionized water to prevent cross-contamination. Rinsed sampling equipment that was in the well with deionized water. Drained flow through cell.
13) Transported equipment to next sampling location, minimizing contact with surfaces that came in direct contact with a sample.

Sampling trips took two days to complete. The following day analyses were started at the ISWS laboratory. All samples were analyzed within the sample holding times specified in the QAPP.

Geology of Spring Grove Fen and the Surrounding Area

Determination of the geology of Spring Grove Fen and it's surroundings was necessary to delineate the thickness and distribution of geologic materials which have a direct impact on the existence and continual maintenance of the fen. It was essential that a detailed geologic framework be established in order to place observation wells in appropriate horizons, and to understand the geologic controls on the flow of ground water into the site, through the site, and to its discharge in Nippersink Creek. The ISGS and ISWS examined well records to help determine the succession of geologic materials surrounding Spring Grove Fen. This was particularly useful to verify that the upland deposits south of the fen are composed of sand and gravel. A large residential subdivision on the uplands provided an ample number of logs. In addition, a sand and gravel extraction operation on the western side of the uplands (about 2.6 km southwest of the fen) further verified the presence of thick deposits of sand and gravel. Observation wells were constructed and used to: 1) increase the amount of detailed geologic knowledge of the site, and 2) have locations where water levels could be measured and water chemistry samples could be taken.

Previous Geologic Investigations

The complex geology of the Spring Grove Fen area and McHenry County in general has been studied before by the ISGS (Anderson and Block, 1962; Hackett and McComas, 1969; Specht and Westerman, 1976; Masters, 1978; Berg et al., 1985; Berg, 1994). Most recently, Curry et al. (1997 in press) utilized information from all of the above investigations, and added considerable data from a controlled test-drilling program (Curry, 1995). Thousands of logs of water wells were also evaluated, and detailed cross-sections and maps depicting new geologic interpretations were made to provide county planners, developers, and industry with detailed and up-to-date geologic information to help resolve land-use and resource problems. Much of the discussion on geologic materials at Spring Grove Fen is summarized from Curry et al.

Regional Physical Setting

Most of eastern McHenry County, including the Spring Grove Fen area lies on the Wisconsin till plain composed of sediments deposited during the last glaciation, from about 25,000 to 15,000 years ago. The Fox River flows from north to south as it flows between McHenry and Lake Counties. Nippersink Creek flows eastward into the Fox River. The regional setting of Spring Grove Fen is common to many fens and other wetlands in McHenry County. It lies in a lowland floodplain (on the south side of Nippersink Creek) and is adjacent to an upland composed of coarse-grained sand and gravel deposits capped by diamicton of the Haeger Member. The Haeger is a fairly continuous deposit on uplands throughout eastern McHenry County. Figure 13 is a north-south cross-section from north of Nippersink Creek to the uplands which shows the relationship of the fen to its topographic and geologic setting.

Glacial History (modified from Curry et al., 1997, in press)

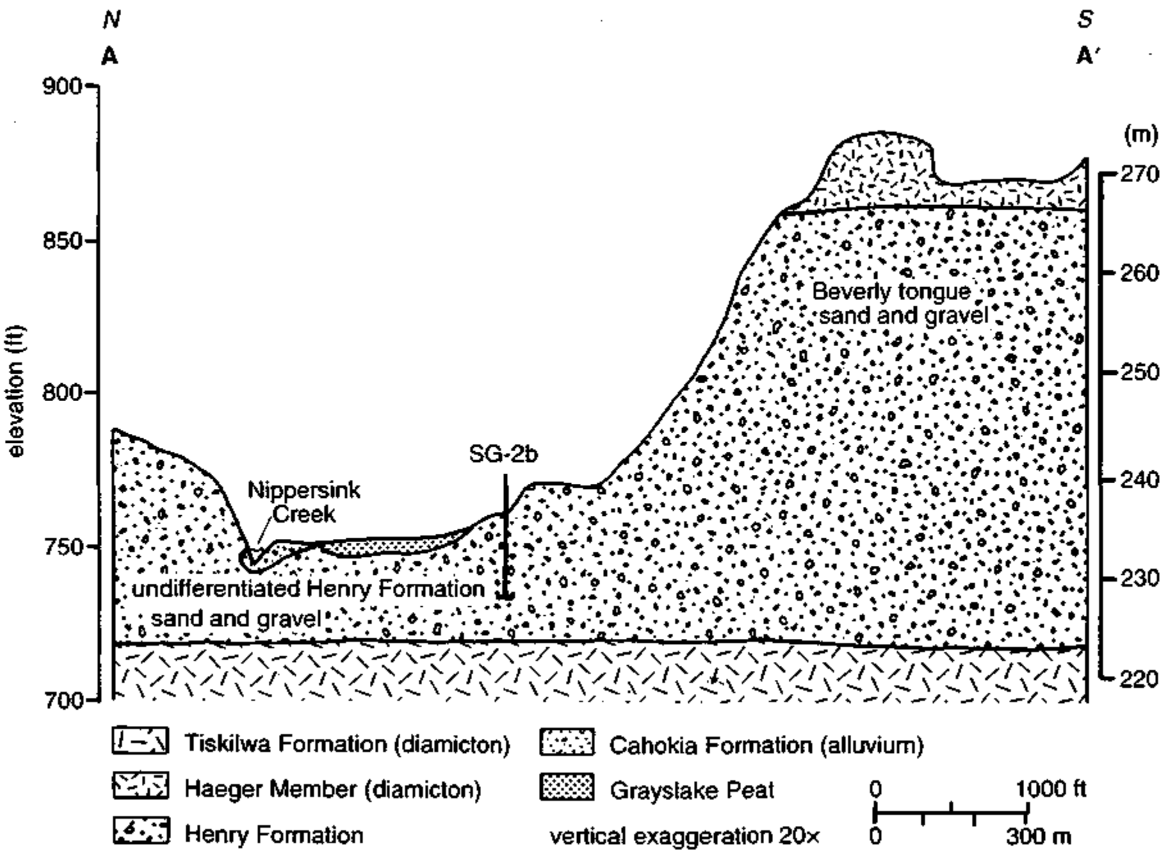
The geologic history of Spring Grove Fen and McHenry County in general is complex, involving deposition of numerous materials associated with multiple fluctuations of continental glacial ice during the Quaternary Period. This tongue of ice was part of the great Laurentide Ice Sheet, which covered much of the Great Lakes region of North America during at least two major glaciations over the last 300,000 years.

The Illinois Episode occurred from 300,000 to 130,000 years ago (Johnson, 1986). After the Illinois glacial Episode, was a long period of soil formation. As the Lake Michigan Lobe formed and approached Illinois about 25,000 years ago, the landscape of McHenry County was covered with spruce forests, and was inundated by seasonal dust storms that deposited *loess* (wind-blown silt). The first advance of the Lake Michigan Lobe occurred about 25,000 years ago when glacial processes constructed the Marengo Moraine in western McHenry County and *diamicton* (a mixture of sand, silt, clay, and gravel) of the Tiskilwa Formation was deposited. The regional characteristics of the sediments deposited during the last glaciation in northeastern Illinois is discussed by Wickham et al. (1988) and Graese et al. (1988).

The Cary Moraine, west of the Spring Grove area acted as a dam for a large lake which was in front of an advancing glacier or *proglacial*. This lake occupied much of northeastern McHenry County. A diamicton called the 'Yorkville Member' was deposited at this time in southeastern and south-central McHenry County. However, a combination of unmelted glacial ice and the proglacial lake prevented the ice which deposited the Yorkville from extending into the Spring Grove area in northern McHenry County.

A sublobe of glacial ice again became active, and deposited the thick sand and gravel deposits of the Beverly Tongue. Proglacial alluvial fans were overrun by the active ice margin in uplands covering much of northeastern McHenry County, including the Spring Grove Fen area.

Figure 13. Cross section A-A'



As glacial ice melted from McHenry County, the ice margin retreated northward to Milwaukee, and then readvanced to deposit the Valparaiso Morainic System just east of McHenry County. The lowlands associated with the Fox River, Nippersink Creek, and Chain-'O-Lakes evolved as the ice slowly melted away. Regional evidence suggests that deglaciation began in McHenry County about 15,000 years ago (Hansel and Johnson, 1992), however, additional radiocarbon data on organic sediments are needed to confirm this assumption.

The modern landscape reflects the glacial legacy presented above, and modern processes have slowly eroded away the sediments that the glacial ice deposited. During this most recent chapter in the geologic history of McHenry County, rivers have continued to transport, remove, and deposit alluvium. Mass movements (e.g., landsliding) have eroded steep slopes. Peat and lake sediments have accumulated in landscape depressions and chemical and physical processes have altered surficial materials as soils have formed.

Local Geologic Units

Sediments deposited in the Spring Grove Fen area are associated with glaciation from about 25,000 to 12,500 years ago and include those of the Wedron Group and Henry Formation of the Mason Group. They are:

- ► Tiskilwa Formation and the Haeger Member of the Lemont Formation (diamictons)
- ► Henry Formation (sand and gravel outwash deposits), and
- ► Equality Formation (fine-grained lake sediments).

Non-glacial surficial deposits covering the Wedron and Henry units and deposited from about 12,500 years ago to the present include:

- ► Peoria Silt (windblown silt),
- ► Grayslake Peat (organic sediments), and
- ► Cahokia Formation (alluvium or river sediments).

Geologic units described at Spring Grove Fen as well as the surrounding area were identified on the basis of stratigraphic position (where the deposit lies with respect to other overlying and underlying deposits) and physical characteristics (color, texture, particle sorting, etc.). Following is a discussion of the geologic deposits of Spring Grove Fen and surrounding area beginning with the lowermost deposits encountered while drilling:

<u>Tiskilwa Formation</u>

Diamicton belonging to the Tiskilwa Formation was discovered beneath sand and gravel at a depth of 11.9 m (39 ft) in boring SG-lb and 12.8 m (42 ft) in boring SG-2b. The unit is chiefly composed of reddish brown to pinkish clay loam diamicton and is identified by its distinctive color, particle-size distribution, and clay mineralogy (Wickham et al., 1988). The thickest known occurrence of this unit in Illinois, about 88.7 m (291 ft), is in northwestern McHenry County below the Marengo Moraine. This is the thickest known occurrence of diamicton deposited during a single advance of the Lake Michigan Lobe in Illinois, an event known as the Marengo Phase of the Michigan Subepisode (Hansel and Johnson, 1992; Hansel and Johnson, 1996). This sediment is considerably thinner in the Spring Grove area where it is probably less than 15 m (50 ft) thick. The Tiskilwa is composed of an average of 36% sand, 37% silt, and 27% clay (Curry, 1995).

Beverly Tongue of the Henry Formation

The thick sand and gravel comprising the upland south of Spring Grove Fen, and possibly some of the sand and gravel deposits overlying the Tiskilwa Formation at the fen belong to the Beverly Tongue of the Henry Formation. The Beverly is close to 30 m (100 ft) thick in the upland south of the fen. Surface elevations are over 268 m (880 ft) above mean sea level (MSL), while the base of the slope and elevation of the fen are about 238 m (780 ft) above MSL. Throughout McHenry County, the Beverly Tongue is a thick and extensive surficial aquifer and it has been extensively mined as an aggregate resource (Masters, 1978). Sediments comprising the Beverly Tongue are generally stratified and not uniform in texture. The Beverly often is characterized by crudely stratified bouldery, gravelly sand, well-sorted, finely cross-bedded medium to coarse-grained sand, and discontinuous beds of uniform silty clay.

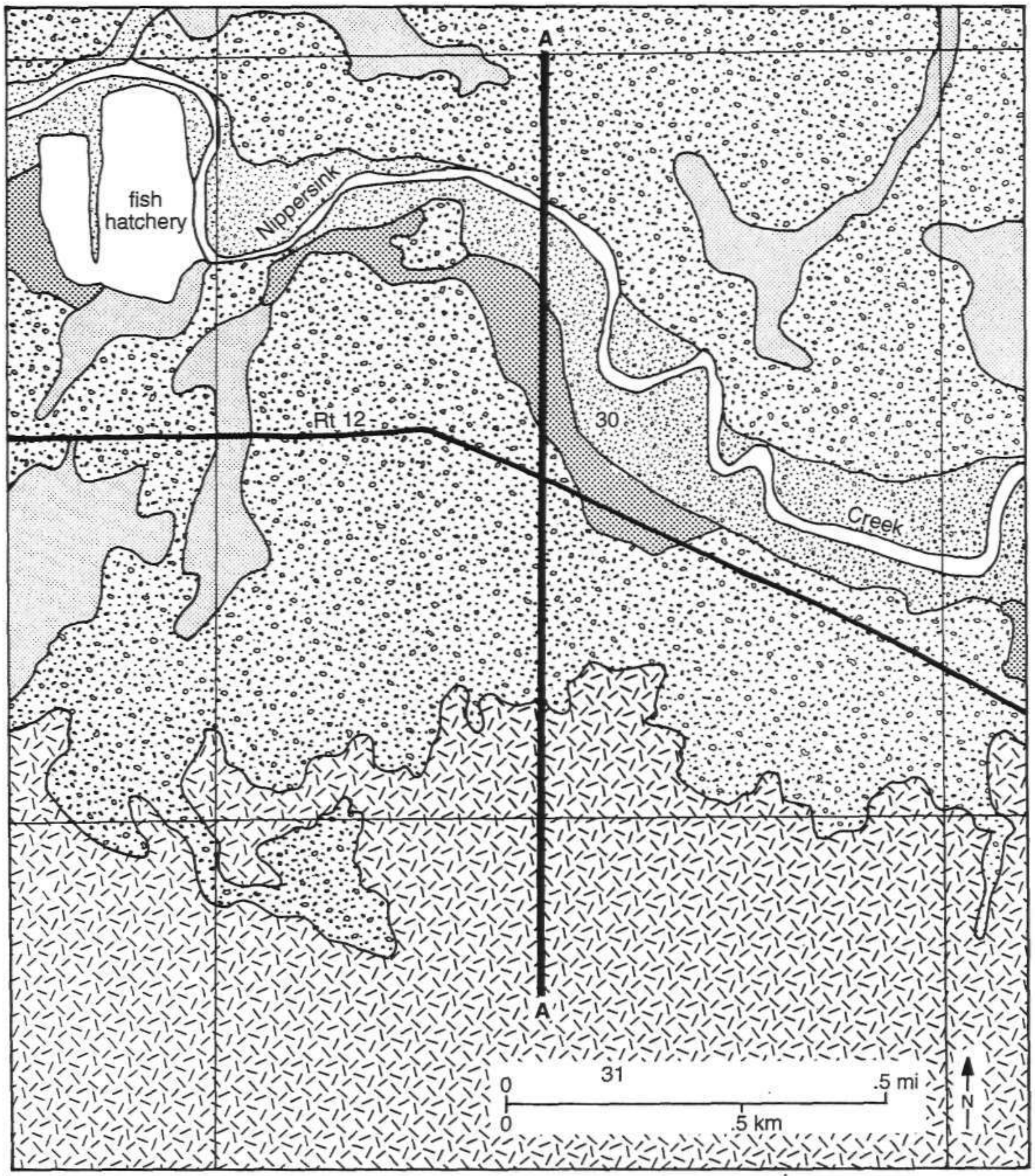
Haeger Member of the Lemont Formation

The Haeger Member is found above the Beverly Tongue and is present locally in the Spring Grove area on the top of the upland south of the fen. It is composed of a yellowish-brown sandy loam diamicton with discontinuous lenses of sand and gravel, as well as thin beds of uniform silty clay and silt. The diamicton on the upland is less than 6.1 m (20 ft) thick, however in portions of north-central McHenry County, the Haeger is as much as 21.3 m (70 ft) thick. The Haeger Member is the surficial deposit on uplands across most of eastern, central, and north-central McHenry County. It is composed of an average of 52% sand, 35% silt, and 13% clay (Curry, 1995). However, the Haeger is locally more sandy and gravelly and often difficult to distinguish from the underlying sand and gravel of the Beverly Tongue.

Undifferentiated Henry Formation of the Mason Group

Undifferentiated Henry Formation is composed primarily of vaguely stratified layers of boulders, gravel, and sand, and beds of cross-stratified, well-sorted, medium- to fine-grained sand. It is commonly found in the low lying areas of floodplains where it is a surface or near-surface deposit. In the floodplain area of Nippersink Creek, which includes Spring Grove Fen, the sand and gravel of the floodplain is juxtaposed with the sand and gravel of the uplands immediately to the south. Therefore it is difficult to separate the undifferentiated Henry Formation from the Beverly Tongue. On the surficial deposits map for the Spring Grove Fen area (Figure 14), both undifferentiated Henry Formation beneath the floodplain and the Beverly Tongue of the Henry Formation on the uplands are shown as one surficial unit.

Figure 14. Surficial geologic map of the study area



Haeger Member (diamicton)

Cahokia Formation (alluvium)

Beverly tongue (sand and gravel)

Beverly tongue (fine grained and stratified)

Grayslake Peat (may be overlain Cahokia Fm in some places)

Equality Formation of the Mason Group

The Equality Formation is composed of finely-bedded to uniform silt and clay and it often tongues with the sand and gravel of the Henry Formation. This is particularly evident on the western side of the fen in boring SG-3. The fine-bedding, fine-grained texture, fossil content, and landform association imply that the Equality Formation was deposited in lakes. Fine- to coarse-grained sand layers of the Henry Formation that intimately tongue with silt and clay of the Equality Formation are common in northeastern McHenry County. The thickest known occurrence of Equality is adjacent to Lake Pistakee where structural borings revealed silt and clay to depths greater than 30 m (100 ft). The silt and clay is interbedded with well-sorted sands of the Henry Formation.

Peoria Silt

Peoria Silt only occurs as a thin deposit on top of the upland south of the fen. It is always modified by soil forming processes, and is composed of leached, often organic rich, silty clay less than about 1.2 m (4 ft) thick.

Grayslake Peat

Grayslake Peat is composed of organic soils, including fibrous to mucky peat and marl. It is the surficial material covering most of Spring Grove Fen. It also covers large areas across McHenry County, however, it is often less than 0.9 m (3 ft) thick. The thickest Grayslake Peat in McHenry County likely occurs in the Chain-O-Lakes lowlands, on the margins of lakes, and in broad reaches of the floodplain along the Fox River valley.

Cahokia Formation

The Cahokia Formation is composed of alluvial deposits. It occurs as a surficial deposit along Nippersink Creek and appears to be interbedded with Grayslake Peat over a portion of Spring Grove Fen. The Cahokia principally is composed of well-sorted sand within and adjacent to channels, and fines laterally away from channels to organic-rich silty clay. The Cahokia commonly is underlain by sand and gravel of the Henry Formation and below floodplains, such as the Nippersink Creek floodplain, the Cahokia overlies fine sand of the Henry or silt and clay of the Equality.

Geology of Spring Grove Fen

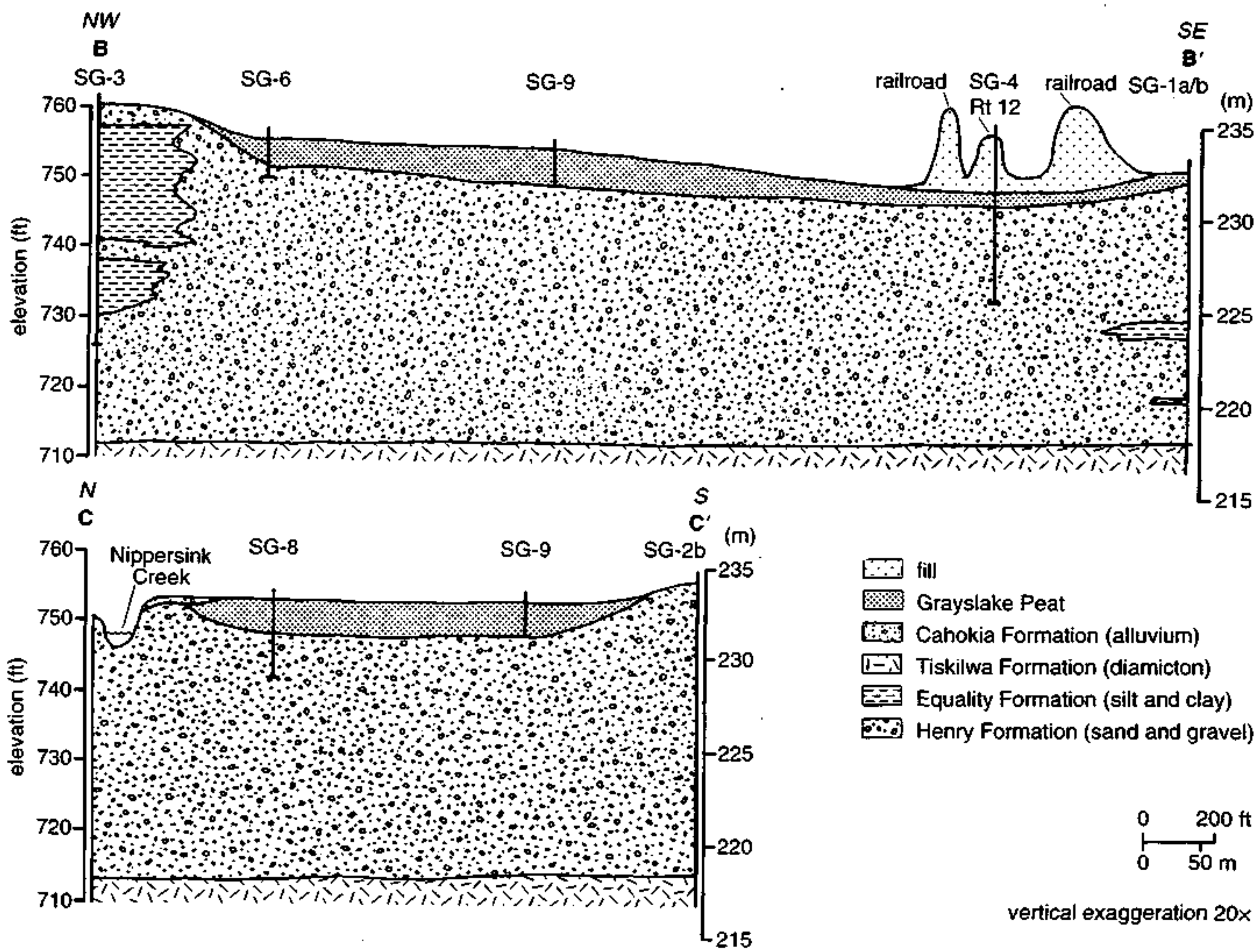
A map of geologic materials at land surface for Spring Grove Fen and the surrounding area was produced by classifying soils from the McHenry County Soil Survey (Ray and Wascher, 1965) into geologic parent material groups from which soils developed (Figure 13). The region was centered around Section 30 of T. 46 N., R. 9 E. (which includes Spring Grove Fen) and extends about one-half mile to surrounding sections. Five primary geologic materials were deduced from the mapped soils: (1) sandy loam diamicton of the Haeger Member, (2) coarse-grained outwash of the Henry Formation, (3) medium and fine-grained stratified outwash of the Henry Formation, (4) alluvium of the Cahokia Formation, and (5) organic-rich Grayslake Peat.

Figures 13 and 14 show that diamicton of the Haeger Member is continuous on the relatively flat uplands south of the fen. The Haeger is eroded along the northward-facing slope of the uplands. Here the surficial geologic material is primarily the coarse-grained sand and gravel of the Beverly Tongue of the Henry Formation. This material undoubtedly merges with the finer-grained sand and gravel of undifferentiated Henry Formation associated with the Nippersink Creek valley, however, a clear boundary is not evident. Finer-grained components of the Henry are visible about 0.8 km (0.5 mi) west of the fen, as well as northwest and northeast of the creek. The coarse-grained Beverly Tongue deposits dominate the surficial geology north of Nippersink Creek. Alluvium of the Cahokia Formation is visible along the entire extent of Nippersink Creek, while organic sediments of the Grayslake Peat occupy three closed depressions on the floodplain. The area of Grayslake Peat which comprises Spring Grove Fen is in the center of the Figure 14.

Figure 12 shows the location of two cross sections (Figure 14) through Spring Grove Fen. Cross section B-B' trends northwest-southeast from boring SG-3 to borings SG-1a/b, while cross section C-C trends north-south from Nippersink Creek through borings SG-8, 9, and 2b. Both cross-sections show a relatively uniform succession of geologic materials at the site: Tiskilwa Formation diamicton is at a depth of about 12.2 - 13.7 m (40-45 ft), overlain by Henry Formation sand and gravel. The Grayslake Peat is the material at the surface over a portion of the site and is commonly about 0.6 m (2 ft) thick, however, at boring SG-8 it is about 1.5 m (5 ft) thick.

Of particular interest is the succession of materials revealed by borings SG-4 and SG-3. At SG-4, about 2.4 m (8 ft) of fill material was placed on top of the Grayslake Peat, presumably when US Route 12 and/or the railroad was constructed. The Grayslake Peat is about 0.6 m (2 ft) thick at boring SG-4. The succession of geologic materials at boring SG-3, located just beyond the northwest boundary of the fen, is different from the succession of materials at all other borings at the site area. Instead of a succession of peat underlain by thick sand and gravel of the Henry Formation, about 7.6 m (25 ft) of Equality Formation silt and clay dominates the upper 9.1 m (30 ft). Its extent west and southwest of boring SG-3 is unknown, however, it is extensive enough to act as a viable confining unit to the underlying sand and gravel aquifer. Artesian conditions were encountered slightly at a depth of 6.7 m (22 ft) and significantly at a depth of 9.7 m (32 ft). At 6.7 m (22 ft), a very fine sandy layer with silt was encountered. This deposit could be connected with the main body of sand and gravel which underlies the fen, but its continuity can only be speculated. At 9.7 m (32 ft), however, a coarse sand with gravel was found that appears to be continuous with sand and gravel deposits throughout the rest of the site. The hydraulic head at a depth of 9.7 m (32 ft) was sufficient to produce an estimated flow of 15 liters per minute (4 gallons per minute). It appears that the Equality Formation silt and clay pinches out in a southeasterly direction. None was encountered at shallow depths in other borings including SG-6. Thin beds of silt and clay (<0.6 m (2 ft) thick), which may or may not be related to the silt and clay in boring SG-3, were discovered deeper than 6.1 m (20 ft) at boring SG-1b.

Figure 15. Cross sections B-B' and C-C'



Geologic Controls on the Existence of Spring Grove Fen

Critical to the existence and continual maintenance of the fen are: (1) sand and gravel deposits topographically higher than and hydraulically upgradient from the fen and creek, (2) the thickness of sand and gravel deposits beneath the fen, and (3) the presence of fine-grained diamicton (Tiskilwa Formation) beneath the sand and gravel. Ground water contained within the sand and gravel in the uplands and flowing northward toward Nippersink Creek encounters considerably thinner sand and gravel deposits at the base of the upland slope. Water does not readily move through the Tiskilwa Formation and ground-water discharge occurs within the fen because of upward vertical hydraulic gradients. Discharge also occurs at Nippersink Creek because of northward horizontal hydraulic gradients (discussed below).

Hydrology of Spring Grove Fen

Ground-Water Flow

During construction of the well network, particular attention was given to the location of the screened intervals. The observation network was constructed to determine both horizontal and vertical gradients. Over the duration of the study, water level data collected from 9 wells and 2 creek locations (sampling points SG-la, 2a, 4, 5, 6, 8, 9, 10, R-2, N-l, and N-2), were used to construct five hydraulic head maps. Wells that were used for determination of horizontal gradient had well screens placed in the uppermost portion of the surficial sand and gravel of the Nippersink floodplain. An exception to this was the residential well, R-2, which is expected to be in direct hydrologic connection with the main sand and gravel deposits of the floodplain.

From these hydraulic head maps, the direction of ground-water flow and maximum and minimum horizontal hydraulic gradients were estimated. Maps for each of the five sampling periods were constructed. Since all maps show the same general flow patterns only two representative figures are shown (16 and 17). Ground-water flow near Spring Grove Fen is generally north and northeast. Both Nippersink Creek and the hill south of Spring Grove Fen are the dominant factors which control ground-water flow directions. The minimum estimated hydraulic gradient exists in the west portion of the study area and is approximately 6 m/1000 m or 0.006. R-1 was not used in the construction of these maps because the top of the screened interval is 13 m (43 ft) above the elevation at which most of the wells near the preserve are screened. The maximum observed gradient occurs near the center of the preserve and is approximately 3.4 m/200 m or 0.017. The maps were constructed with data from R-2 which has the top of its screened interval approximately 17 m (56 ft) below the elevation at which most of the wells near the preserve are screened. It is reasonable to assume that a well which was screened shallower than R-2 and deeper than R-l would have a water level between those of R-l and R-2. Using 240 m (787 ft) as an estimate, the gradient in the southern half of the map would then be significantly greater than that shown, perhaps as much as 12 m/500 m or 0.024. If this were the case, the maximum gradient would be present in the southeast and the minimum gradient would be in the northwest.

Figure 16. Hydraulic head map from the first sampling quarter (8/95)

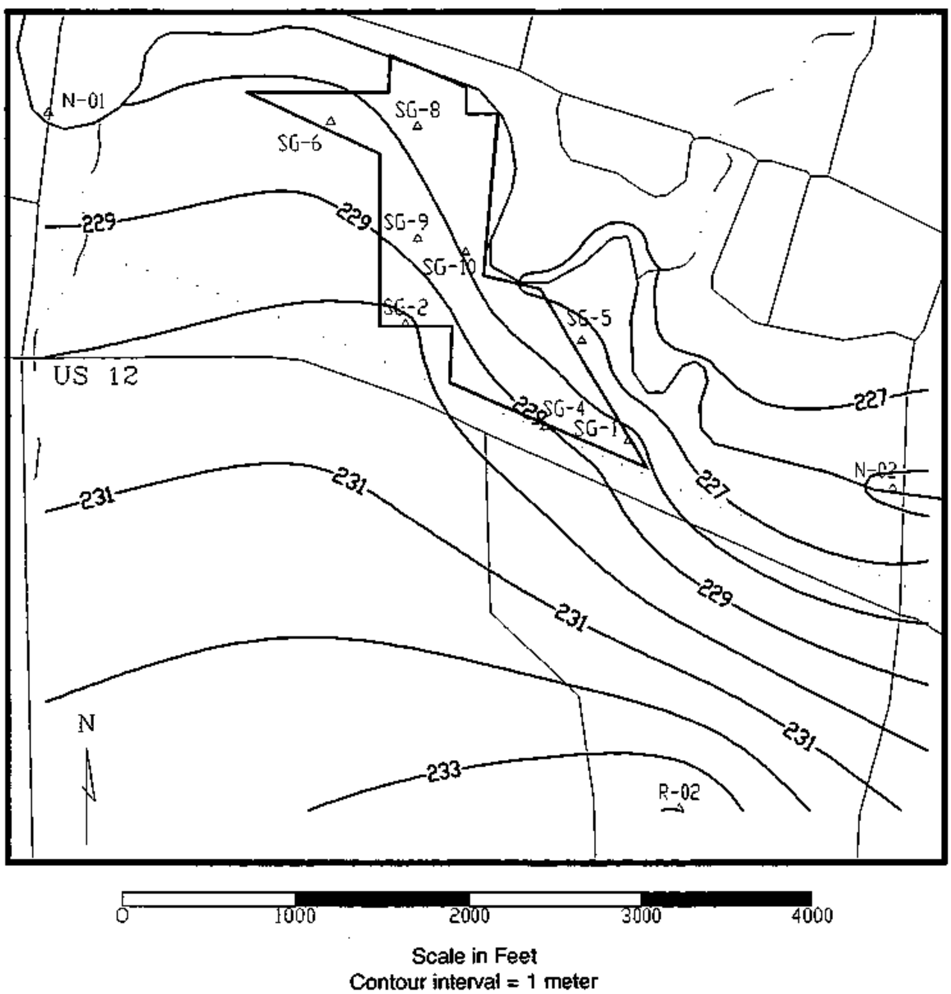
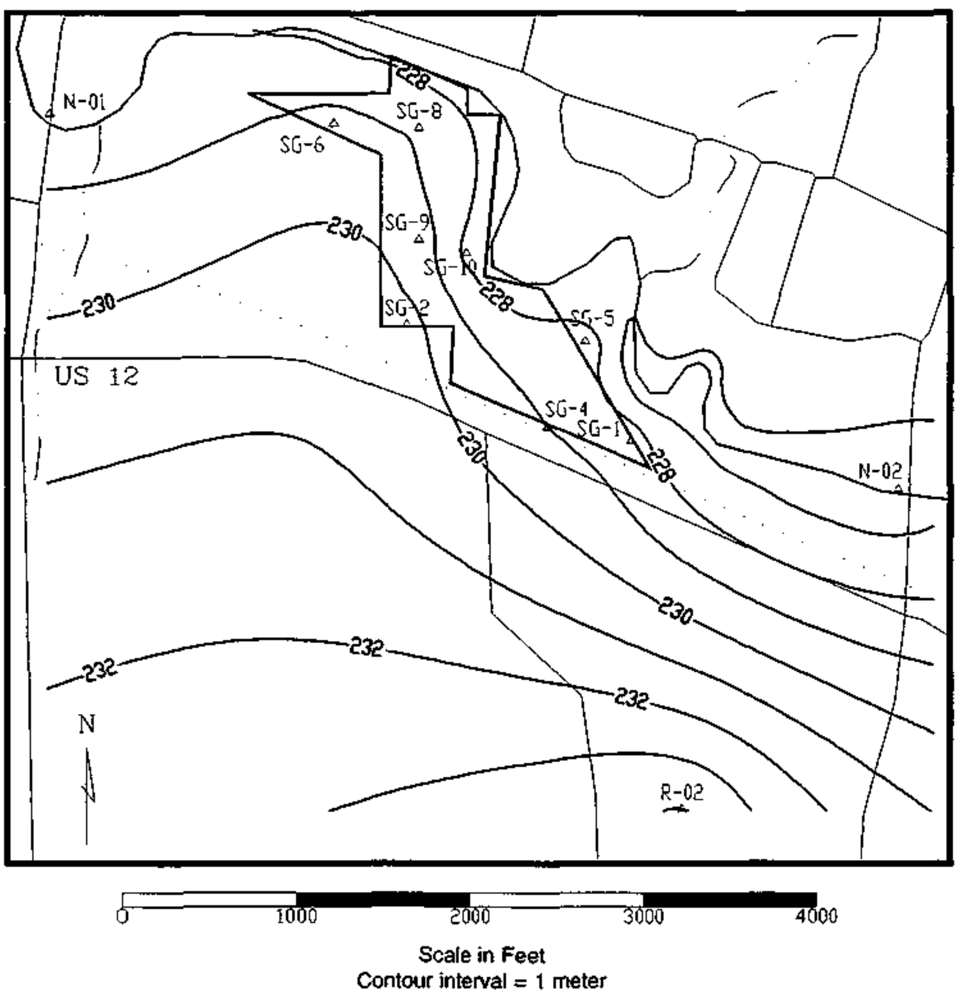


Figure 17. Hydraulic head map from the third sampling quarter (4/96)



Two sets of wells were used to determine the vertical gradients at locations where ground water enters Spring Grove Fen (SG-1a/b and SG-2a/b). Both upward and downward gradients were seen at SG-1a/b. The average upward gradient was 0.30 m/6.60 m or 0.045. The only downward gradient (0.10 m/6.60 m or 0.015) was seen in the second quarter. Both upward and downward gradients were also seen at SG-2a/b. The average upward gradient was 0.04 m/6.52 m or 0.005. The only downward gradient (0.13 m/ 6.52 m or 0.020) was seen in the fifth quarter. SG-1a/b has a more significant upward component of ground-water flow because of its proximity to the valley wall (i.e., the hill to the south). However, the occurrence of the downward gradients at the well nests during different quarters suggests that the distance to the nearby hillslope is only one of the factors controlling vertical flow patterns.

One difference between Figure 16 and 17 is the slight variation in ground-water flow pattern in the vicinity of well SG-10. This is partly due to the addition of three wells (SG-8, 9, and 10) to the network in February of 1996. Also, southeast of SG-10 several small channels (~1 m wide) join to form a larger tributary channel of the Nippersink. One of the smaller channels extends northward just west of SG-10. Well density was not sufficient to delineate the effects that these channels have on ground-water flow patterns.

Surface Water Flow

In addition to the channels noted above, significant discharge occurs though a surface water channel which runs parallel to the railroad tracks along the southern border of the preserve. This flow exits the preserve in the southeastern corner near SG-la/b. A partially plugged culvert is located between SG-4 and SG-la/b and it allows runoff from Highway 12 to flow northward through the railroad bed and into the preserve. Several other surface water features occur within the preserve. Because shallow ground-water levels are usually near the land surface, ponding and surface water flow elsewhere in the preserve is highly dependent on recent climatic conditions. One major area of ponding exists in the northern part of the preserve east of SG-6. Diffuse seepage on the western side of the preserve is eventually concentrated in small channels (<0.5 m wide) which have developed between tussocks. These small channels contribute to the area of ponding and the larger channels described earlier. Surface water that discharges from the preserve contributes to the flow of Nippersink Creek.

Nippersink Creek discharges to the east. The average difference in measured water levels between sampling points N-1 and N-2 was 2.06 m during the five sampling periods. Since N-1 and N-2 are approximately 2600 m apart, the average gradient between them was 2.06 m/2600 m or 0.001. Mean daily flow and precipitation values for a nearby stream gaging station run by the United States Geological Survey (USGS) are shown in Figure 18. This station is located less than 2.6 km (1 mi) upgradient of N-l on the Nippersink near Winn Road. The maximum daily mean flow over the period of record (1966-1996) at this station was 2580 cubic feet per second (cfs) on February 21, 1994. The minimum daily mean flow over the same time was 10 cfs on August 6, 1988. Throughout quarterly sampling, two periods of low flow and one period of high flow occurred. These periods correspond to the late summer/early fall of 1995 and 1996 and the late spring/early summer of 1996. It is therefore more representative to compare the monthly mean data of the individual water years with the monthly mean data over the period of record (Figure 19). During the

Figure 18. Daily mean flow and precipitation values at USGS station 5548280 (8/94-12/96)

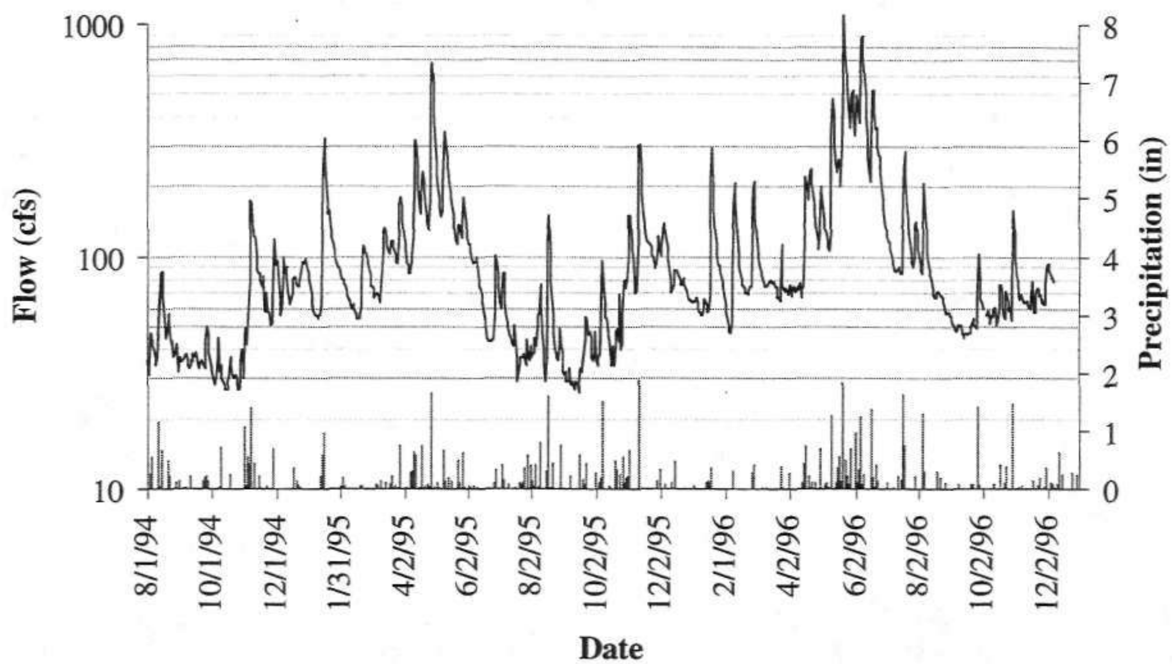
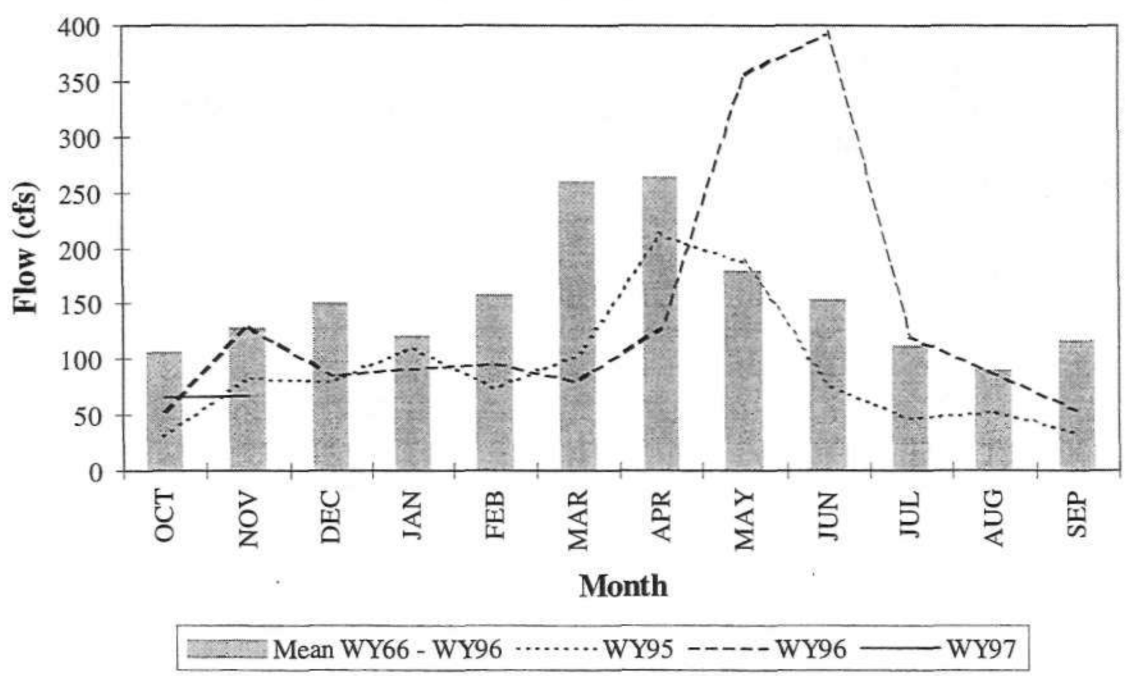


Figure 19. Monthly mean flow values at USGS station 5548280 by water year



quarterly sampling, monthly mean flows were generally lower than the mean for the period of record. One notable exception is during May and June of WY 96 when flow was nearly double the mean for the period of record.

Water Quality at Spring Grove Fen

Sampling Results

Sixty-four sets of samples were analyzed by the ISWS. Fifty sets were taken from the monitoring network, six sets were field duplicates, and five sets were trip blanks. A piper diagram (Figure 20) illustrates the major anion and cation concentrations found at sampling points during the first quarter. These samples and those from other quarters belong dominantly to two hydrochemical facies (i.e., compositions): the calcium (cation) facies and the bicarbonate (anion) facies. Samples for other quarters plotted similarly to those shown in Figure 20.

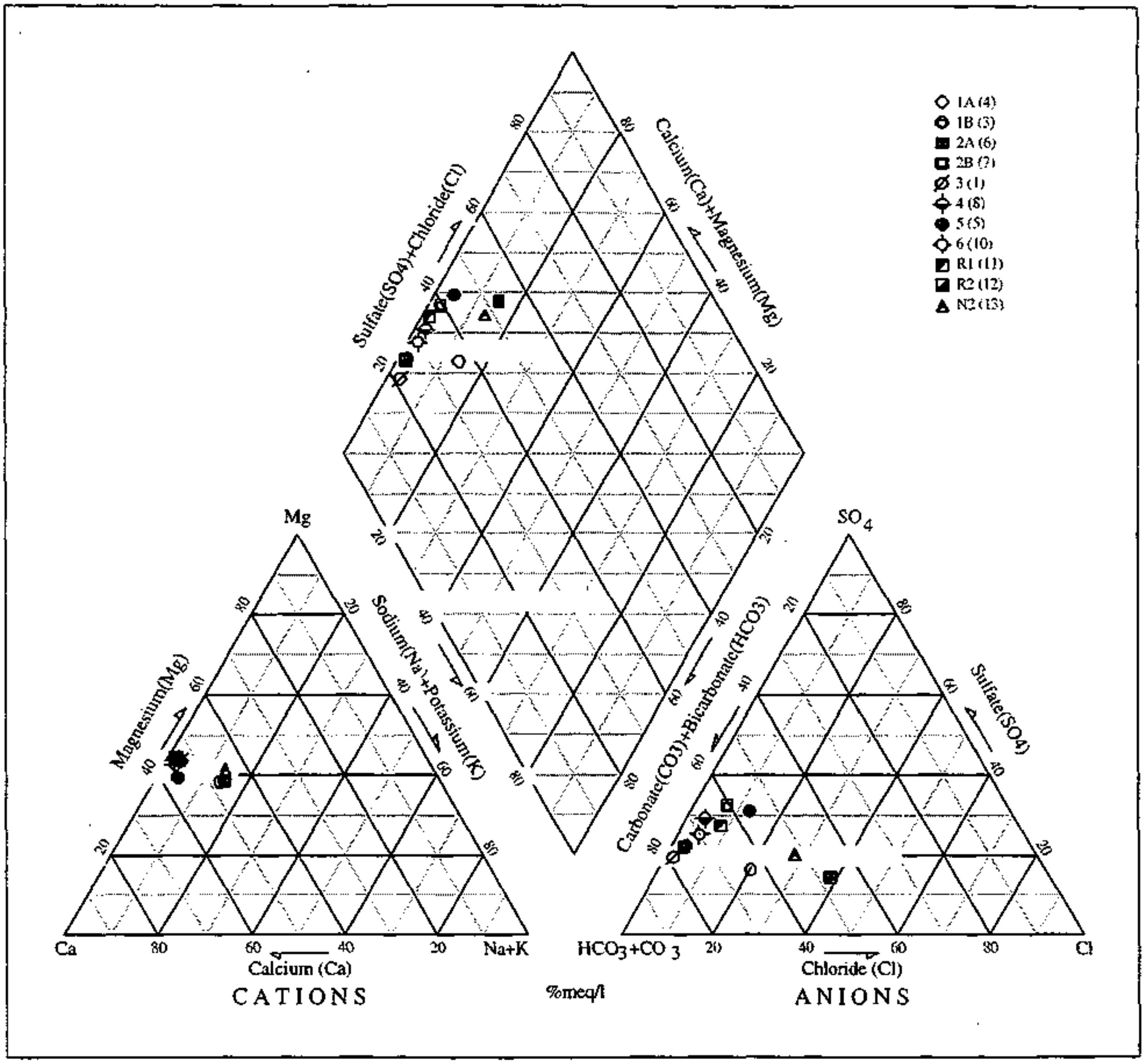
Many dissolved cations which occur in ground or surface waters are found only in trace amounts. Analytes in Table 7 that were not detected above the MDL or were detected slightly above the MDL include: Al, Ag, As, B, Be, Cd, Co, Cr, Hg, Li, Mo, Ni, P, Pb, Sb, Se, Sn, Ti, Tl, V, simazine, prometon, alachlor, alachlor oxoacetic acid (OXA), acetochlor ethanesulfonic acid (ESA) and OXA, and hydroxy-atrazine. While each element could be compared rigorously, only major anion, cation, and organic analytes will be addressed in this report. The maximum and minimum detections of all analytes over the duration of the study are shown in Table 7 and detailed sample results are presented in Appendix G.

Throughout the five quarters of sampling elevated concentrations of several analytes were seen in SG-2a. Those analytes included: Ba, Fe, Mn, Na and alachlor residues. Historically dumping has been known to occur in the vicinity of the well. Therefore, SG-2a may be influenced by the chemistry of those fill materials. It is also possible that a residential septic system located southeast of the well influenced the chemistry at SG-2a.

Anions

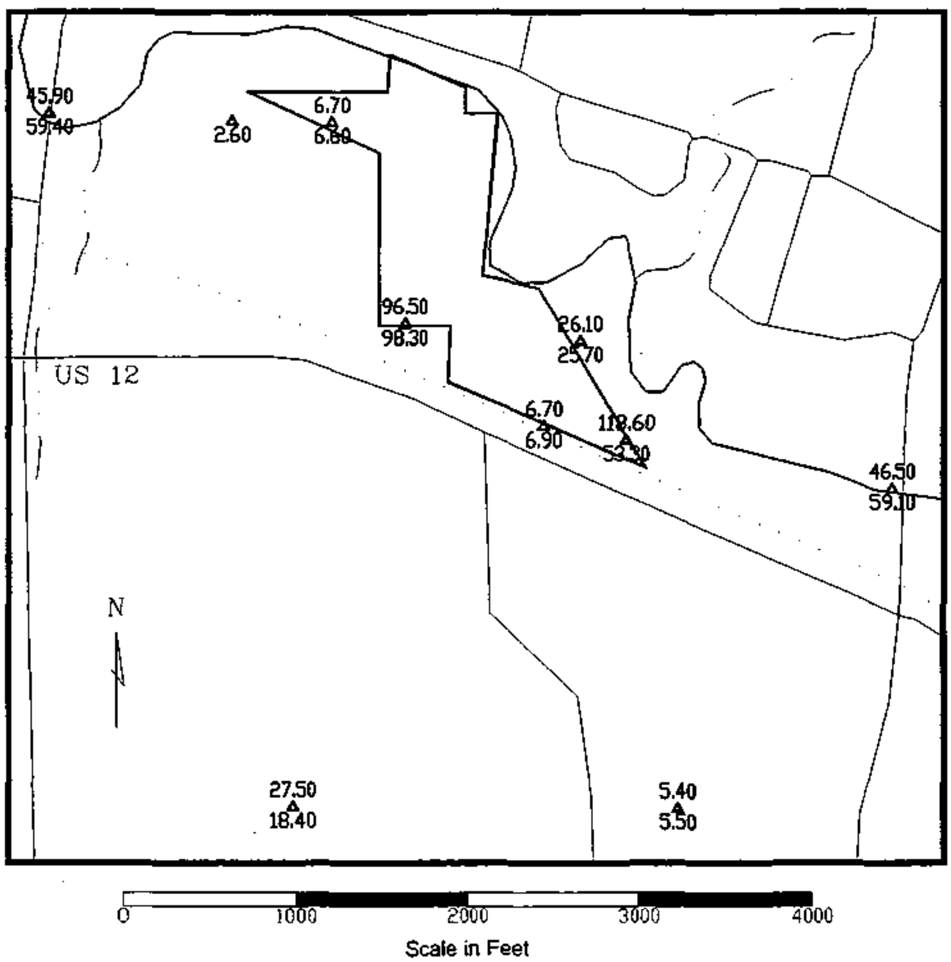
The major, minor and trace anions in general order of abundance were bicarbonate (HCO_3^-), chloride ($C1^-$), sulfate, ($SO4^{2-}$), nitrate (NO_3^-), fluoride (F^-), and phosphate ($H_2PO_4^-$and HPO_4^{2}). Bicarbonate is assumed to be the major chemical species present (as opposed to carbonic acid or carbonate) because of the range of pH (6.70 to 8.56). A major factor controlling the presence of bicarbonate is the dissolution of carbonate minerals (e.g., $CaCO_3$) in the subsurface. Surface-water samples from N-1 and N-2 consistently had higher pH than ground-water samples. Concentrations of calcium (64 -85 mg/L) and alkalinity (250 - 300 mg $CaCO_3$/L) in the surface-water samples are only slightly lower than those seen in ground-water samples. Calcium concentrations in ground-water samples ranged from 76 to 114 mg/L and alkalinity ranged from 294 to 439 mg/L. This data suggests ground-water discharge into Nippersink significantly influences its chemistry.

Figure 20. Piper diagram of first quarter samples from Spring Grove Fen
(Numbers in parentheses are the ISWS sample identification number)



Chloride concentrations were generally below 20 mg/L for wells SG-1b, 2b, 4, 6, R-1, and R-2. These sampling locations are deeper and farther away from potential chloride sources (e.g., roads) than are wells SG-1a, 2a, 5 and creek locations N-1 and N-2. Even though SG-4 is the well closest to Highway 12, horizontal and upward vertical gradients would not allow chloride to penetrate to the depth of the screened interval nearly 4 m (13 ft) below the roadway. Chloride, however, may be mobilized through the drainage ditch on the north side of Highway 12. This drainage enters the nature preserve near the southeast corner of the preserve and may be partially responsible for the highest observed chloride concentration in SG-la on June 10,1996 of 118.6 mg/L (Figure 21).

Figure 21. Fourth quarter (6/96) and average chloride concentrations at monitoring points
(Fourth quarter values are noted above the triangle showing the sampling location.
Average values for all five quarters are noted below the sampling location)



Increased mobilization of chemicals in the subsurface often occurs during spring because of increased infiltration of soil moisture and precipitation. Observation of chloride increases after spring suggests that chloride takes a significant amount of time to travel both vertically and horizontally. These high concentrations also occur during a period of increased precipitation and stream flow (i.e, increased local ground-water and surface-water movement). It is expected these factors affected the concentration and timing of chloride seen in SG-1a. The closest analog to SG-1a is SG-2a. Even though reported concentrations of many analytes (TDS, Ba, Fe, Mn, and Cl) were consistently higher in SG-2a than other wells, the maximum observed concentration of chloride (121 mg/L) occurred at SG-2a on October 18, 1996. It is important to remember that both wells were screened between approximately 2.5 and 3.3 m (~ 8.3 and 10.8 ft) below the land surface, and concentrations of chloride above or below the screened intervals are unknown.

Nitrate concentrations ranged from below the detection limit (0.02 mg N/L) to 6.71 mg N/L. Nitrate was not present or was present in low concentrations in and near the preserve at locations SG-la, lb, 4, 5 and 6. Generally, wells with lower or non-existent nitrate values showed either weakly oxidizing or reducing conditions at the time of sample collection. Denitrification, the alteration of nitrate into nitrogen gas (N_2) or nitrous oxide (N_2O), is controlled by bacteria, oxygen availability, and the quantity of carbon available to facilitate the denitrification reaction. It is presumably responsible for the observed low values of nitrate within the preserve.

Cations

The major, minor and trace cations in general order of abundance were calcium (Ca^{2+}), magnesium (Mg^{2+}), sodium, (Na^{+}), iron ($Fe_{(total)}$), manganese (Mn^{2+}), strontium (Sr^{2+}), and barium (Ba^{2+}). The major source of calcium and magnesium is the dissolution of carbonate minerals (e.g., limestone, $CaCO_3$ and dolomite, $CaMg(CO_3)_2$) in the subsurface. As noted above, concentrations of calcium and alkalinity in the surface-water samples are only slightly lower than those seen in ground-water samples (Figure 22). Magnesium followed a similar trend with concentrations of 37 to 46 mg/L seen in surface-water samples and concentrations of 35 to 57 mg/L seen in ground-water samples.

Sodium occurred in the highest concentrations at SG-la, 2a, N-1 and N-2 (Figure 23). While deicing salts may be a source of sodium and chloride in the area of Spring Grove Fen, variation in natural soil chemistry of the floodplain soils may also influence sodium values at SG-1a and 2a. Generally, sodium is less mobile than other conservative elements such as chloride.

As for minor and trace cations, iron concentrations ranged from below detection to nearly 2 mg/L. Iron concentrations tend to be elevated in wells that had reducing or slightly oxidizing potentials (SG-2a, 4, and 5). Elevated concentrations of manganese occur in samples from wells SG-1b, 2a, and 5 and some of those samples also have elevated iron concentrations. Strontium and barium consistently occur at low concentrations (< 0.200 mg/L) in all samples taken.

Figure 22. Average calcium and magnesium concentrations at monitoring points
(Average values for all five quarters shown above (calcium)
and below (magnesium) the sampling location)

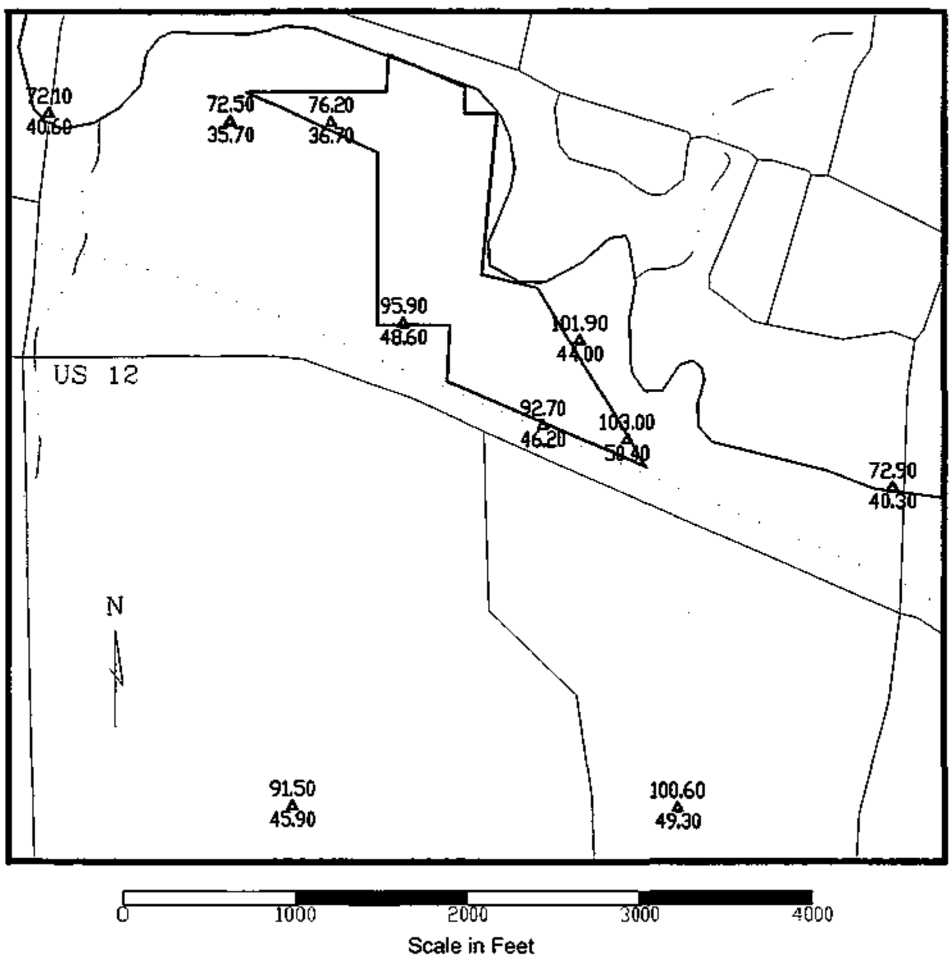
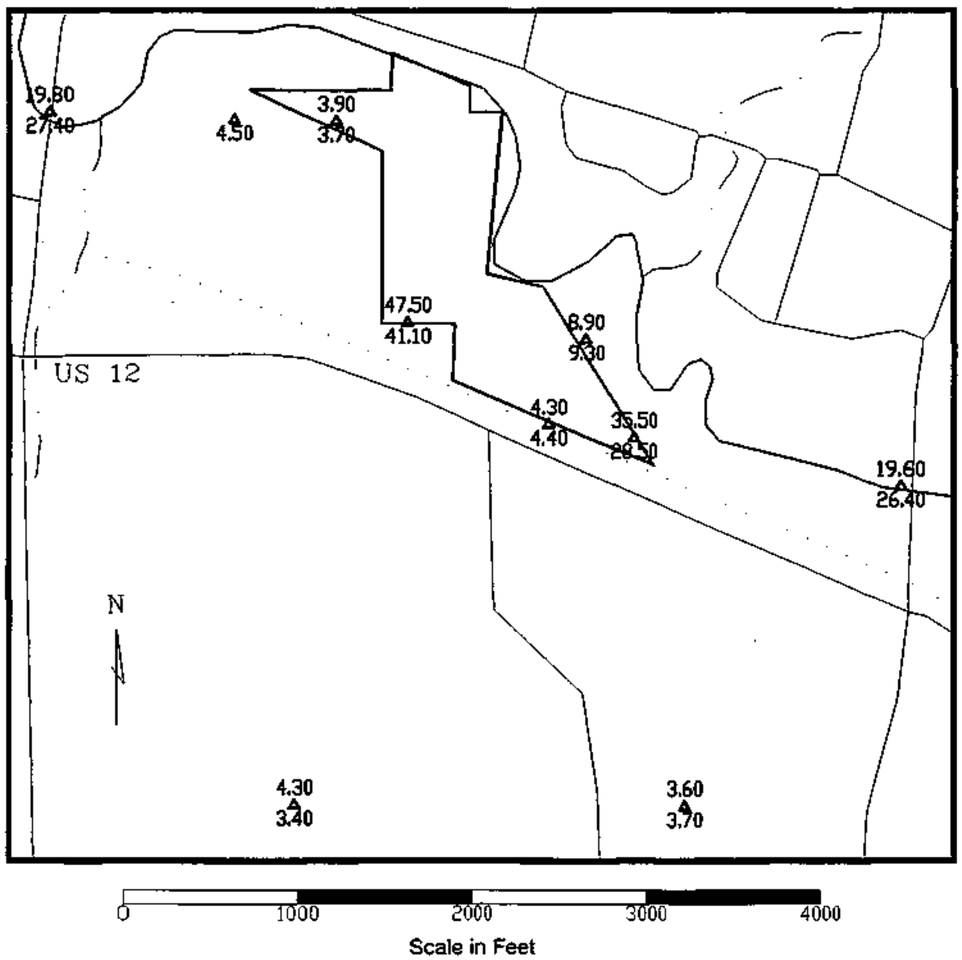


Figure 23. Fourth quarter (6/96) and average sodium concentrations at monitoring points
(Fourth quarter values are noted above the triangle showing the sampling location.
Average values for all five quarters are noted below the sampling location)



Organic Compounds

Immunoassays were conducted for 2,4-D, alachlor and triazine residues in the first four quarters of sampling. Alachlor residues were tested for during the fifth quarter, but triazine and 2,4-D residues were not because of the low percentage of positive detections in previous quarters. During the second through fourth sampling quarters, GC analysis confirmed the existence of alachlor (0/23) and atrazine (4/6) parent compounds in those samples which tested positive by immunoassay. Many of these detections were at or slightly above the method detection limit. It was assumed that the positive detections for alachlor residues were being caused by one or several herbicide breakdown products. Samples that tested positive by immunoassay for alachlor residues during the fifth quarter were analyzed for six ESA and OXA metabolites of alachlor, metolachlor, and acetochlor, in addition to hydroxy-atrazine. Analyses were conducted by the Organic Chemistry Laboratory of the USGS - Water Resource Division in Lawrence, Kansas. Several potential cross reactants (alachlor ESA, metolachlor ESA and OXA) were identified in low concentrations (< 3 µ g/L).

Alachlor, 2,4-D, and triazine residues are generally associated with agricultural activities. Positive detections were consistently seen in SG-2a, 2b, 5, N-1 and N-2. During the fifth quarter, diazinon, a commonly used residential pesticide, was added to the list of GC analytes. Concentrations were reported near the method detection limit for SG-4 and N-l.

Analyses for fifty-nine volatile organic compounds (see Appendix F) were performed during the first and third quarters. These compounds are generally associated with industrial activities and were not detected in any samples from the Spring Grove Fen area.

Quality Assurance and Control Summary

Data Precision

Data precision was assessed by the collection and analysis of 6 field duplicate sets per 50 sample sets (12%). Ten sets of lab duplicates were also analyzed. A relative percent difference (RPD) of up to 20 percent between a duplicate and original sample analysis was acceptable for concentrations (in the original sample) above the MCC. For concentrations below the MCC and above the MDL, an RPD of up to 100 percent was allowed. The RPD was calculated for each sample and its duplicate according to the following equation:

$$RPD= \{(S-D)/[(S+D)/2]\} * 100$$

Where S = original sample value
D = duplicate sample value

For the six sets of field duplicates, the RPD was calculated for 133 pairs of original/duplicate concentrations. Relative percent differences for 129 (97.0%) of those pairs were acceptable with 115 (86.5%) pairs having an RPD within 10 percent of the original value. RPD criteria were exceeded in samples 19/20 (Alachlor by ELISA), 33/34 (Fe and Mn), and 56/57 (TKN). Variability in timing and methodology of sample collection may be responsible for concentration variations between samples 33/34 and 56/57, but are probably not responsible for variation between samples 19/20.

For the ten sets of lab duplicates, the RPD was calculated for 149 pairs of original/duplicate concentrations. Relative percent differences for 144 (98.6%) of those pairs were acceptable with 112 (76.7%) having an RPD within 10 percent of the original value. RPD criteria were exceeded in samples 25/25-LS (A1) and 45/45-LS (TKN). Variation between 25/25-LS is expected because of proximity to the MDL (MDL Al = 0.029 mg/L, sample 25 = 0.035 mg Al /L). Reasons for variation between 45/45-LS were not identified.

Data Accuracy

Data accuracy was assessed by the collection and analysis of field blanks to test sampling procedures and lab matrix spikes to test lab procedures. Five sets of field blanks per fifty sample sets (10%) were taken to spot check for sample bottle contamination. Sample 39 showed an anomalous value for zinc. No values of over 0.051 mg Zn/L were seen in other samples from the fourth quarter. However, increased values for zinc were seen in fifth quarter samples (53, 54, 60, and 61).

Six sets of laboratory matrix spikes per 50 sample sets (12%) were prepared and 228 analyses of spiked samples were performed by the ISWS Laboratory. Percent recoveries (%R) of 50 to 150 were acceptable for this project and were calculated by the following formula:

$$\%R = [(A - B)/C] * 100$$

Where A = analyte concentration determined experimentally from the spiked sample
B = background level determined by a separate analysis of the unspiked sample
C = amount of the spike added

Percent recoveries were within the described criteria for 226 (99.1 %) of the analyses. Sample 13-S exceeded criteria for both potassium (%R = 39.5) and sodium (%R = 8.5).

Data Completeness

Data completeness is a measure of the amount of valid data obtained from a measurement system compared to the amount that was expected to be obtained under normal conditions. Data completeness of 90 percent was defined as acceptable to meet project goals. A percent completeness (%C) of 99.8 was calculated for the field and lab chemistry data reported in Appendix G by the following formula:

$$\%C = 100 * (V/T)$$

Where V = number of measurements judged valid
T = total number of measurements

Data Representativeness

Data representativeness expresses the degree to which data accurately and precisely represent a characteristic of a population, parameter variations at a sampling point, a process condition, or an environmental condition. The sampling network was designed to provide data representative of site conditions. The total dissolved solids analysis was compared with the sum of other analytes (e.g., anions, cation, etc.) as a guide to the representativeness of an individual sample. All relative percent differences were less than 10 except for samples 42, 43, and 50. Ion balances were also calculated by reported anion and cation concentrations and all samples were within +/-10% error and therefore judged to be representative. Percent error (%E) was calculated by the formula:

$$\%E = ((\text{sum of cations} - \text{sum of anions})/(\text{sum of cations} + \text{sum of anions}))* 100$$

SUMMARY AND RECOMMENDATIONS

Summary

During this study methods were developed and utilized to assess nature preserve sensitivity and vulnerability to potential ground-water contamination. First, a shallow ground-water sensitivity map of the state (1:500,000) was prepared using GIS techniques. It predicts the potential for movement of contaminants from the surface into shallow ground water based on soil leaching characteristics and depth to the uppermost aquifer. Two hundred seven nature preserves were screened and nearly half of them were categorized as having high or very high sensitivity to ground-water contamination.

Second, site surveys were conducted at the 85 nature preserves which were expected to be most sensitive to ground-water contamination. Hydrologic, geologic, and land-use information was collected for the sites and surrounding areas prior to the surveys. This data was used during the surveys and can be used for future interpretations and comparisons. Roughly 30% of the sites were classified as having moderate to high or high vulnerability. The development and use of a field evaluation form facilitated site surveys and the subsequent entry of field data into an electronic database. These types of surveys should be conducted at all nature preserves to provide a standard set of background information for future decision making.

Third, the geology and hydrology of Spring Grove Fen Nature Preserve in McHenry County were characterized in greater detail. Test drilling was conducted and 10 observation wells were installed. Sixty-four sets of ground-water and surface-water samples were collected quarterly and analyzed routinely for 35 constituents between August 1995 and October 1996. Increased chloride concentrations (up to 121 mg/L) were observed in and upgradient of the preserve. Use of deicers on nearby roads may be responsible for an increase in chloride of over 500% at well SG-la. Low concentrations of alachlor metabolites (< 3 µ g/L) were seen in observation wells and in Nippersink Creek. Low concentrations of triazine residues (< 1 µ g/L) were also seen in Nippersink Creek. Chemical data at Spring Grove Fen supports the assessment of the site being highly vulnerable to contamination. This type of chemical sampling is important to establish existing water quality at preserves for comparison to future conditions.

Recommended Special Resource Ground-Water Designations

As stated in the Illinois Administrative Code (State of Illinois, 1994), ground-water that contributes to a dedicated nature preserve can be designated as a Special Resource Ground Water. Therefore, the limiting factor in designation of preserves is the collection of the necessary information for a written request to the IEPA. Sufficient information is expected to be available in Volume II of this report and the Directories of Nature Preserves (1995a and 1995b) for 85 preserves to be listed by the IEPA for Special Resource Ground Water designation. For the remaining twothirds of the preserves in the INPS, a programmatic approach is suggested to collect hydrogeologic information so additional written requests can be made. Since some of the information gathered for Special Resource Ground Water designation and preserve dedication is the same, it may be appropriate to gather such information for proposed nature preserves simultaneously.

Methods developed during this study could be used on sites other than nature preserves. Special Resource Ground Water designation may be appropriate for sites that are identified as having a ground-water vulnerability of moderate or above. These would be sites with sensitive geology and potential sources of contamination. Use of this approach may be particularly significant in the protection of Illinois' natural areas.

Presently, clarification is needed for several aspects of Special Resource Ground Water designation. Specifically, the process and intended areas of designation should be delineated further. Using a nature preserve boundary as the area of designation does not seem to address the issue of ground-water contamination. It is however a readily defined area for which information can be collected. If only ground water within a preserve was designated and then monitored for quality or quantity changes, impacts could not be anticipated or addressed properly. In this case, by the time an impact was identified at a preserve, activities responsible for the impact could already be well established. Alternatively, designating areas described by certain ground-water conditions (e.g., upgradient of the preserve) would be more scientifically valid.

Future Work

In association with this project, an issue paper (Compilation and Interpretation of Hydrogeologic Data at State Nature Preserves and Natural Areas) was developed. It identified concerns and possible actions related to further study of nature preserve and natural area vulnerability to contamination. It also expressed the need for a systematic and continuous effort in compiling and interpreting hydrologic and geologic information. The paper identified tasks that would focus Survey efforts, first, on those sites undergoing pressures from nearby land uses, and second, on remaining sites as time permitted. In this way, crucial information could be compiled, interpreted and made available in a timely manner for INPC and IDNH decision makers.

Activities Proposed in the Issue Paper

Activities proposed by the Surveys are summarized in Figure 24 and are briefly described below. Information would be gathered on two scales. On a statewide scale, available regional environmental information that may be important for subsequent site assessments would be identified, assembled, and published. Such information may include statewide average precipitation, runoff relationships, soil erodability, stream quality, and regional aquifers characteristics. This would provide a readily available compendium of reference information that can be used to aid additional site vulnerability assessments.

Figure 24. Summary of proposed tasks for continued assessment of state-managed lands

Task 1. *Identification and Prioritization of State-Managed Lands (SMLs) for Assessment*
- *A.* Select and prioritize state-managed lands for assessment
- B. Initiate identification of available regional information for SML assessments

Task *2. Compilation of Available Regional Information for SML Assessments*
- *A.* Compile Regional Data
  - *i.* Identify available GIS coverages
  - *ii.* Create new GIS coverages where feasible
- B. Publish compiled information after Year One

Task 3. *Preparation of Vulnerability Assessments of Prioritized SMLs*
- *A.* Collect and compile available site-specific data
- B. Conduct site visits
- C. Determine site vulnerabilities
- D. Transfer compiled site-specific information
  - *i.* Enter selected data into electronic database
  - *ii.* Transfer site "Hydrology File" to INPC/IDNH
  - *iii.* Make information on assessed preserves available on Internet (optional)
  - *iv.* Submit annual letter-type progress report

Task 4. *Response to Special Request Assessments*
- *A.* Receive request from INPC or IDNH and compile necessary information
- B. Prepare response in the form of a letter-report

Task 5. *Initiation of Site-Specific Monitoring —separately funded on an as-needed basis*

On a local scale, available site-specific hydrologic and geologic information would be compiled and interpreted on sites selected by INPC, IDNH, and the Surveys to assist site managers with decisions regarding specific land use pressures and the potential for impacts on state-managed lands. State-managed lands (SMLs) refers specifically to nature preserves and natural areas. Data compilation and interpretation at the local scale would closely follow the design used in site assessments described in this report. However, additional surface water assessment methods may be developed and incorporated. As the information is compiled and interpreted at the local scale, this data can be entered into the electronic database previously described.

If a request is forwarded to the Surveys from the INPC or IDNH for specific site information to handle a problem requiring prompt action, efforts of Survey staff can be directed toward that need. Once the request is satisfactorily resolved, efforts can be directed back toward the regional and local work. It is estimated the regional information will be assembled and published after the first year. Site-specific information gathering is seen as a continuous process. It is also expected that major efforts will be directed toward communicating with other investigators and managers to increase site-specific data collection.

Task 1. Identification and Prioritization of State-Managed Lands for Assessment. The Surveys have compiled and interpreted information on 85 sites within the INPS. A list of those sites grouped by their Survey-assessed vulnerability was shown earlier (Figures 9 and 10). A systematic approach of selecting and prioritizing from among the remaining 176 nature preserves and 1194 natural areas must be conducted. The classified sensitivities of 122 preserves (Figure 25) can serve as a basis for prioritizing future assessments. Refinements to this list should be done based on consultation with INPC and IDNH as well as additional sensitivity classifications. Priority should be given to those sites which fell into the very high sensitivity rating and which are judged by department personnel to face potential stresses from nearby land uses or land-use changes.

Most nature preserves have electronic data (e.g., site boundaries) readily available for sensitivity assessments. This information should be updated to include boundaries for all sites within the INPS. While natural areas have very similar features as nature preserves, they are much greater in number (1194 natural areas vs. 261 nature preserves) and do not have similar boundary data available. For regional sensitivity determinations to be made, natural area boundaries would need to be digitized on a sufficient scale for sensitivity analysis.

Task 2. Compilation of Available Regional Information for SML Assessments. The Surveys will identify and compile available regional (i.e., statewide) data sets and maps that can be used to aid subsequent site assessments. Such a compilation will also be valuable in identifying what information is available and where it can be found (i.e., data source). This compendium will be published approximately one year after the start of this project. Mappable data sets include but are not limited to:

Average annual precipitation and periodic precipitation maxima and minima
Rainfall-runoff relationships
Water quality of surface and ground waters and historical trends
Stream discharge
Aquifer boundaries and yield
Soil erodability
Land surface topography

The report will become a reference document providing pertinent available regional information to aid in subsequent site assessments. Where publication of a mapped data set is not practical, a description of the data, possibly a representative portion of the data, specific reference to the availability of that data set, and contact person(s) and agencies of the data source (e-mail addresses and web site addresses) will be cited. This can provide a list for subsequent investigators to check against for site assessment completeness.

Task 3. Preparation of Vulnerability Assessments of Prioritized State-Managed Lands. After the SMLs have been prioritized, compilation of site-specific information for assessing SML vulnerability to surrounding land uses will also begin. Approximately 15 sites can be evaluated in the first year in addition to the aforementioned regional compilation and assuming no major requests

Figure 25. Sensitivities of 122 preserves where vulnerability assessments were not made

Low (20)
- American Beech Woods
- Bartlett Woods
- Big Creek Woods Memorial
- Hetzler Cemetery Prairie
- Hybernia
- Jasper Co. Prairie Chicken Sanctuary
- Liberty Prairie
- Loda Cemetery Prairie
- Lusk Creek Canyon
- Marissa Woods
- Posen Woods
- Piney Creek Ravine
- Prospect Cemetery
- Robeson Hills
- Rock Cave
- Rocky Branch
- Short Pioneer Cemetery Prairie
- Sunbury Railroad Prairie
- Temperance Hill Cemetery
- Weston Cemetery Prairie

Moderate (48)
- Ayers Sand Prairie
- Baber Woods
- Beall Woods
- Belmont Prairie
- Black Partridge Woods
- Brownlee Cemetery Prairie
- Byler Cemetery Savanna
- Bystricky Prairie
- Margery C. Carlson
- Cave Creek Glade
- Chestnut Hills
- Colored Sands Bluff
- Crevecouer
- Denby Prairie
- Russell M. Duffin
- Fairchild Cemetery
- E.E. Fawks Bald Eagle Refuge
- Carl Fliermans' River
- Foley Sand Prairie
- Funks Grove
- Glenbrook N. High School Prairie
- Gooseberry Island
- Halesia
- Hooper Branch Savanna
- Howard's Hollow
- Jubilee College Forest
- Manito Prairie

Moderate (continued)
- Marion Co. Prairie Chicken Sanctuary
- Massauga Prairie
- Mehl's Prairie
- Morton Grove Prairie
- ParkLands
- Paw Paw Woods
- Raccoon Grove
- Reed-Turner Woodland
- Ridgetop Hill Prairie
- Roberts Cemetery Prairie
- Round Bluff
- Cap Sauers Holdings
- Shoe Factory Road Prairie
- Somme Prairie
- Spitler Woods
- Spring Grove Cemetery
- Stubblefield Woodlots
- Thomson-Fulton Sand Prairie
- Thorn Creek Woods
- Tomlinson Pioneer Cemetery Prairie
- Wards Grove

High (17)
- Black Hawk Forest
- Burton Cave
- Busse Forest
- Forest Park
- Forest Park South
- Greenlee Cemetery Prairie
- Grubb Hollow Prairie
- Harlem Hills
- Harper's Woods
- Munson Township Cemetery
- Myer Woods
- Norris
- G.S. Park Memorial Woods
- Plum Grove
- Robinson Park Hill Prairies
- Severson Dell
- Witter's Bobtown Hill Prairie

Figure 25. (cont) Sensitivities of 122 preserves where vulnerability assessments were not made

Very High (37)

- Beach Cemetery Prairie
- Berryville Shale Glade
- William & Emma Bohm Memorial
- Brookhill Lutheran Cemetery Prairie
- Brown Barrens
- Carpenter Park
- Cary Prairie
- Freeport Prairie
- Fults Hill Prairie
- Henry Allan Gleason
- Grant Creek Prairie
- Harper-Rector Woods
- Hartley Memorial
- Kankakee River
- Julius J. Knobeloch Woods
- Laona Heights
- Lloyd's Woods
- Long Branch Sand Prairie
- MacArthur Woods
- McClure Shale Glade
- Meredosia Hill Prairie
- Mississippi River Sand Hills
- John M. Olin
- Ozark Hills
- Pere Marquette
- Revis Hill Prairie
- Sagawau Canyon
- Salt Creek Woods
- Sand Prairie-Scrub Oak
- C. & C. Marie Sands/Main St. Prairie
- Sentinel
- Starved Rock
- Stemler Cave Woods
- Tomlin Timber
- Douglas A. Wade Prairie
- Wier Hill Prairie
- Wirth Prairie

are forwarded by INPC or IDNH. Approximately 30 sites per year can be evaluated in following years assuming no major requests from INPC or IDNH. A process similar to that followed for this study was recommended. Specific data needs at any particular site will depend upon issues specific to that site. As part of the reporting process, selected information may be made available on the Internet. Creation of a web site containing information on each preserve or natural area, with maps of each site, and links to other related information sources is an exciting option for providing the information to site managers and the public.

Task 4. Response to Special Request Assessments. One of the overriding reasons for the preparation of the issue paper was the recognized need for supporting INPC and IDNH site managers with hydrologic and geologic information. Often, this information is needed to make decisions quickly on proposed land-use developments that may have an impact on state-managed lands. Such threats can not always be anticipated and input may be required on fairly short notice. This program would allow such request work to come to the Surveys and to be handled in a routine manner. Steps similar to those described for site vulnerability assessments will be followed, only perhaps in a more concentrated manner. In some cases, information may have already been assembled through a previous assessment.

Task 5. Initiation of Site-Specific Characterization and Monitoring. This task will be carried out on an as-funded basis upon a specific request from INPC or IDNH, in consultation with the Surveys. Because the nature preserves and natural areas cover such a wide variety of terrains and sizes, costs for characterization and monitoring will be unique to each site. Steps similar to those used in the Spring Grove Fen characterization would be used.

Other Activities

Other activities which were not expressly identified in the issue paper would also be valuable. These activities include:

1) *Continuation of monitoring at Spring Grove Fen* - General background water quality has been identified and is now available for comparison with new data that is collected. More rigorous sampling for chloride would further identify current extent and effects on the preserve. Additional sampling in the future similar to that conducted during this study may identify longer term impacts of development on Spring Grove Fen.

2) *Development of a comprehensive and readily accessible water quality database specifically for preserves* - Within the last three to five years a great deal of monitoring and scientific investigation has occurred at selected preserves. The raw data is usually not easily accessible or consistently referenced. Researchers could be solicited for raw chemical data which would expedite collection of baseline water quality data at preserves. Incorporation of this information into the Ground-Water Quality Database at the ISWS would provide long term storage as well as other benefits to the INPC, the ISWS, and researchers in general. Access to this information could then be readily provided via a web site.

3) *Development of an annotated bibliography of hydrologic/geologic work done at nature preserves and natural areas* - As work of other researchers was identified during this study, a reference to the research was noted and filed in the appropriate site folder. However, to take full advantage of previous research a thorough literature search could be conducted. An annotated bibliography could then be compiled relating to hydrologic and geologic issues.

4) *Development of a practical field guide for data collection at preserves* - Development of a field guide would help increase cost-effective data collection at preserves. Such a guide could include: Grouping of preserves into landscape types to guide site instrumentation, description of major water inputs and outputs for each landscape type, cost effective data collection by local parties with guidance/instrumentation by the Surveys, description of standard methods for installation of wells/staff gages/monitoring devices, and identification of necessary data to answer ground-water and surface-water issues. As a part of this effort, workshops could be given to site managers and other local personnel.

5) *Graphic analysis of aerial photographs at vulnerable sites* - While graphic analysis of the scans or orthophotos of Spring Grove Fen was not performed, this should be done in the future. Such analysis at Spring Grove Fen and other preserves would help identify site origin, historic land use changes, and additional management issues.

6) *Assessment of water quantity changes at preserves due to high capacity wells* - Preserves that may be affected by changes in water quantity could be identified in a search of the ISWS Public-Industrial-Commercial Well Database. Potential impacts could then be identified and addressed.

7) *Design and performance assessment of buffer strips for reduction of contaminants entering nature preserves* - Use of constructed buffer strips could be investigated and designs intended to reduce sediment and chemical contamination of preserves could be assessed. Emphasis could be placed on contaminant sources that preserves face statewide (e.g., septic systems, road runoff, etc.).

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APPENDIX A:

GIS Analysis of Sensitivities of 85 Nature Preserves and
Surrounding Areas Within 0.8 Kilometers of Preserve Boundaries
(Grouped by preserve sensitivity)

INPC No.	Nature Preserve Name	Preserve Sensitivity (percent of total area*)						Sensitivity of Surrounding Area (percent of total area*)							Ground Water Vulnerability Rating
		VH	H	M	L	DL	SW	VH	H	M	L	DL	SW	SL	
198	Barber Fen	100						89							Moderate
225	Churchill Prairie	100						53	25	23					Moderate
128	Elizabeth Lake	100						70	6				5	19	Moderate
233	Farm Trails North	100						62	6	31					Low-mod
196	Ferson's Creek	100						67	31	3					Moderate
113	Forest Glen Seep	100						34		65					Mod-high
209	Fox River Fen	100						74	26						Mod-high
43	George B. Fell	100						73		27					High
214	Glacial Park	100						94	3				3		Moderate
204	Gladstone Fen	100						100							Mod-high
1	Illinois Beach	100						54	11			8		27	Low-mod
135	J. & R. Parker Fen	100						70	22	8					Mod-high
185	Lake in the Hills Fen	100						80	3	2	5	9			High
217	Lake Renwick Heron Rookery	100						100							Mod-high
110	Lockport Prairie	100						88		12					Mod-high
91	Lyon's Prairie & Marsh	100						89	11						Moderate
155	Maramech Woods	100						100							Moderate
84	Massac Forest	100						82					8	10	Low

***Percent of total area:** VH = Very High, H = High, M = Moderate, L= Limited, DL = Disturbed Land, SW = Surface Water, SL = Slivers

INPC No.	Nature Preserve Name	Preserve Sensitivity (percent of total area*)						Sensitivity of Surrounding Area (percent of total area*)							Ground Water Vulnerability Rating
		VH	H	M	L	DL	S W J	VH	H	M	L	DL	SW	SL	
131	Matanzas Prairie	100						98		2					Low-mod
20	Mermet Swamp	100						64		30					Low
166	North Dunes	100						67						33	Low-mod
138	Oakwood Hills Fen	100						87		13					Mod-high
16	Pine Rock	100						100							Low-mod
56	Pistakee Bog	100						100							Mod-high
126'	Romeoville Prairie	100						98		2					High
133	Shick Shack Sand Pond	100						70	19		11				Low
213	Spring Bluff Fen	100						52	13		35				Low
168	Spring Grove Fen	100						100							High
42	Trout Park	100						93	7						Moderate
212	Tucker-Millington Fen	100						100							Moderate
129	Weingart Road Sedge Meadow	100						61					39		Moderate
9	Sand Ridge	95	5					70	28	2					High
120	Palos Fen	85		15				76		24					Low
19	Horseshoe Lake	80					20	56		15			29		Low-mod
24	Franklin Creek	68		32				66		34					Moderate
189	Armin Krueger Speleological	58		42				43		57					Mod-high

***Percent of total area:** VH = Very High, H = High, M = Moderate, L= Limited, DL = Disturbed Land, SW = Surface Water, SL= Slivers

INPC No.	Nature Preserve Name	Preserve Sensitivity (percent of total area*)						Sensitivity of Surrounding Area (percent of total area*)							Ground Water Vulnerability Rating
		VH	H	M	L	DL	SW	VH	H	M	L	DL	SW	SL	
51	Kettle Moraine	57		43				67	2	31					Moderate
146	Bluff Springs	53				47		64				36			High
11	Spring Lake	51	49					65	31	4					Moderate
53	Kinnikinnick Creek		100						100						Low-mod
117	Searls Park Prairie		100					17	83						High
88	Gavin Bog & Prairie		94	6					66	21			12		Mod-high
25	Volo Bog	9	91					66	34						High
23	Miller-Anderson Woods	25	73	1				31	46	12			11		Moderate
195	Almond Marsh			100						78	22				Low-mod
119	Baker's Lake			100						100					Low-mod
158	Barrington Bog			100						100					Low-mod
218	Bonnie's Prairie			100						100					Low-mod
5	Cranberry Slough			100				65		92					Very low
31	Cretaceous Hills			100						100					Very low
235	Exner Marsh			100						93.7	6.3				Moderate
77	Gensburg-Markham Prairie			100											Low-mod
34	Heron Pond - Little Black Slough			100						100					Very low
199	Howard's Hollow Seep			100						85	15				Low

***Percent of total area:** VH = Very High, H = High, M= Moderate, L= Limited, DL = Disturbed Land, SW = Surface Water, SL = Slivers

INPC No.	Nature Preserve Name	Preserve Sensitivity (percent of total area*)						Sensitivity of Surrounding Area (percent of total area*)							Ground Water Vulnerability Rating
		VH	H	M	L	DL	SW	VH	H	M	L	DL	SW	SL	
223	Kishwaukee Fen			100						100					Mod-high
173	LaRue Swamp			100				16		84					Low
184	Miller Shrub Swamp			100						. 88	12				Very low
80	Nelson Lake Marsh			100				2		98					Low
186	Section 8 Woods			100						100					Moderate
83	Wadsworth Prairie			100						100					Moderate
26	Wauconda Bog			100						100					Mod-high
229	Wilkinson-Renwick Marsh			100						100					Low-mod
164	Wolf Road Prairie			100				41		59					Moderate
177	Fogelpole Cave	1		99				36	11	53					Mod-high
21	Goose Lake Prairie			97			3	1		86		2	11		High
244	Bates Fen	4		96				74		26					Moderate
57	Cedar Lake Bog			83			17			73			27		Moderate
181	Wilmington Shrub Prairie			81	18	1		6	10	34	34	16			Moderate
36	Rockton Township Bog	23		77				37		44					Moderate
98	Cotton Creek Marsh	27		73				58		42					High
72	Windfall Prairie	27		73				44		56					Low
165	Momence Wetlands			65	35					41	60				Moderate

***Percent of total area:** VH = Very High, H = High, M = Moderate, L= Limited, DL = Disturbed Land, SW = Surface Water, SL = Slivers

INPC No.	Nature Preserve Name	Preserve Sensitivity (percent of total area*)						Sensitivity of Surrounding Area (percent of total area*)							Ground Water Vulnerability Rating
		VH	H	M	L	DL	SW	VH	H	M	L	DL	SW	SL	
70	Horseshoe Bottom	36		64				33		67					Low
150	Hanover Bluff	37		63				25	2	73					Low
190	Bennett's Terraqueous Gardens	45		55				10		58					Low-mod
105	Chauncey Marsh				100						100				Low
127	Dean Hills				100					7	93				Moderate
96	Pecatonica Bottoms				100			17	12	1	70				Low-mod
216	Skokie River				100					19	81				Low
12	Thornton-Lansing Road				100					7	93				Low
81	Braidwood Dunes and Savanna			16	84					8	69	23			High
167	Turner Lake Fen		10	32	58			34	23	19	24				Mod-high
188	Long Run Seep			45	55			26		74					Mod-high
76	Spring Bay Fen			42			58			44					Low-mod
208	Calamus Lake							91		9					Moderate

***Percent of total area:** VH = Very High, H = High, M = Moderate, L= Limited, DL = Disturbed Land, SW = Surface Water, SL = Slivers

APPENDIX B:

Sample Letter Sent to Natural Resource Conservation Service Offices

Illinois State Water Survey

Hydrology Division
2204 Griffith Drive
Champaign, Illinois 61820-7495
Telephone (217) 333-4300
Telefax (217) 333-6540

February 3, 1995

FIELD(l)

Dear FIELD(2):

The Illinois State Water Survey and the Illinois State Geological Survey are conducting a demonstration project that will assess the vulnerability of selected Illinois nature preserves to ground-water contamination. As part of this project, we are interested in information about land-use or development in the proximity of Illinois nature preserves. Attached are photocopies of nature preserve boundaries within your district that are of interest to us.

Presently, we are looking for an indication of potential threats to the preserves because of land-use changes (for example, residential or industrial development) near the preserves in your area. We would also like to know of possible future developments that are being considered or planned which wouldn't be obvious to an observer visiting the preserves. If no development is being planned, that is important for us to know as well.

From discussion with personnel at the Champaign Co. SWCD, it is my understanding the areas I am interested in probably have not undergone study by the Bureau of Soil and Water Conservation beyond the scope of the Natural Resource Inventory. However, I would welcome your suggestions of agencies to contact or other information which may be helpful.

Please take a few minutes to: 1) jot down what you know about me areas noted above; and 2) indicate the areas of development on the photocopies so we can begin to focus our efforts on those preserves which are most threatened. Thank you in advance for your help. If you have any questions or comments, please contact me.

Cordially,

Randall A. Locke II
Assistant Hydrogeologist
Office of Ground-Water Quality
Phone: (217)333-3866

Enclosures as stated

APPENDIX C:

Field Evaluation Form Used for Site Vulnerability Assessments

ISWS/ISGS Initial Site Assessment of Vulnerability to Contamination

Site: ____________________ Location: ____________________________

Date: ____________________ Field Crew: __________________________

Photos taken (#):______Description: _____________________________
____
____

SAMPLE INFORMATION

Source:	Location:
___ cave	______________________________
___ lake	______________________________
___ observation well	______________________________
___ pond	______________________________
___ seep	______________________________
___ stream	______________________________
___ wetland	______________________________
___ other (describe)	______________________________

	Sample 1	Sample 2	Sample 3	Sample 4
date				
time				
pH				
temp. (° C)				
SC* (µmhos/ cm^2)				
ORP (millivolts)				

*specific conductivity

Were other analyses done? yes _ no _

LAND USE

Past on-site uses (if known):________________________________

PRESENT USES:

suburban residential	on site	off site	location & description

lawns ____

domestic wells ____

above ground
disposal/dumping
(burn piles, etc.) ______________________________________

underground
disposal (septic,
cistern, etc.) ____

other:

industrial/commercial/
municipal

landfills ____

surface
impoundments ____

mining ____

industrial/ commercial/ municipal (cont.)	**on site**	**off site**	**location & description**

stockpiles -

coal ____

road salt ____

building materials ____

other ____

graveyards/ carcasses ____

pipelines ____

sewers ____

above ground disposal/dumping ____

production wells (oil, gas, water) ____

other:

agricultural	**on site**	**off site**	**location & description**
ag fields -			
row crops	__	__	____________
pasture	__	__	____________
orchard	__	__	____________
tree farms	__	__	____________
storage tanks (surface or underground)	__	__	____________
livestock	__	__	____________
surface impoundments/ feed lots	__	__	____________
above ground disposal/dumping (burn piles, etc.)	__	__	____________
drainage wells/ tile outlets/ ditches	__	__	____________
irrigation wells	__	__	____________
rural residential			
domestic wells (infers septic system)	__	__	____________
other: ________	__	__	____________

transportation	on site	off site	location & description
dirt road	__	__	______________________________
gravel road	__	__	______________________________
paved road	__	__	______________________________
railway	__	__	______________________________

Is there potential for run off to impact wetland features on the nature preserve?

yes _ no _

comments - ______________________
____
____
____

on-site recreational

	yes	no	location
outhouses	__	__	______________________________
trail development	__	__	______________________________
parking	__	__	______________________________
other	__	__	______________________________

on-site misc.	yes	no	location
dumping	__	__	______________________________
flood debris	__	__	______________________________

GEOLOGY

What is the primary geologic origin of the site?

_____fluvial/alluvial_____________glacial

_____lacustrine________________eolian

Soils/surficial sediments

association/series - ________________________________

____

____

____

quaternary deposits - ______________________________

____

____

____

Bedrock -

upper lithology -

_____limestone/dolomite_________sandstone

karst: yes_ no_

_____shale _____ coal

supplemental description of bedrock - ________________

____

____

depth to bedrock -_________to________

HYDROLOGY

Inputs:

ground water (depth to, local flow directions, recharge areas)

surface water (proximity, flow directions, drainage area)

Outputs:

ground water -________________________________

surface water -________________________________

Alterations:

type, impact -________________________________

Geomorphology -

Topography -

slope, relief, nearby benchmarks -

Potential for contamination of -

surface water -____

comments -____

ground water -____

comments -____

Initial assessment of vulnerability of wetland site from -

surface water -____

ground water -____

Additional comments or information -

APPENDIX D:

Geologic Logs From Locations SG-1a,**1**b, 2a, 2b, 3, and 4

LOCATION OF BORING	LOGGED BY	DATE	BORING NO.
Spring Grove Fen, E. side. S side of Linden Rd. and N of RR tracks. State Water Survey drilling rig was used. T. 46 N., R. 9E., Sec. 30 SE 1/4	RCB	7/17/95	SG-1a

DRILLING METHOD: auger. Continuous core (CC) + split spoons (SS)

SHEET 1 OF 1

DRILLING	START	FINISH
TIME		
DATE		

WATER LEVEL			
TIME			
DATE			
CASING DEPTH			

DATUM

ELEVATION ~751

SURFACE CONDITIONS:

SAMPLER TYPE	FEET RECOVERED / FEET DRIVEN	Qp	SAMPLE NO. / SAMPLE RANGE	N Blows	DEPTH (ft.)	GRAPHIC LOG	DESCRIPTION
① CC	2.55 / 4				0	FILL	- BROWN FILL
					.85 – 1		10YR (2/1) (bl) ORGANIC PEAT, fibrous spongy
					.12		10YR 4/1 (dk gr) fine - med SAND, some peaty fibers
					.7 – 3	LOSS	gradational to peat above
② CC	2.5 / 3.5				4 – 5		2.5Y 4/1 (dk gr) med SAND with some fibers and fine gravel
					.8 – 6		small - lg GRAVEL, well rounded, calcareous, abrupt boundary to above (up to 3" gravel)
					7	LOSS	
③ CC *	0.4 / 3.5				8 – 10		10YR 4/2 (dk gr br) coarse SAND to 1/2" GRAVEL, well rounded, calc, washed appearance, but indicative of what is there; 4" boulder at 11'
④ SS	0.9 / 2.0			32	11	LOSS	
					12 – 13		10YR 5/2 (gr br) medium SAND to 1/2" GRAVEL, calc, washed look
FINISHED FOR A WELL: TOO MUCH UPWARD HEAD					14 – 15		* switched to SS, CC not effective in s & g.

LOCATION OF BORING	LOGGED BY	DATE	BORING NO.
see SG 1a 5' n. of 1a first spl @ 17.5'	RCB	7/18/95	SG-1b
	DRILLING METHOD: auger SS		SHEET 1 OF 2
DATUM / ELEVATION			DRILLING START / FINISH

WATER LEVEL				TIME	TIME
TIME					
DATE				DATE	DATE
CASING DEPTH					

SAMPLER TYPE	FEET RECOVERED / FEET DRIVEN	Qp	SAMPLE NO. / SAMPLE NAME	N	DEPTH (ft.)	GRAPHIC LOG	SURFACE CONDITIONS:
					10		see SG-1a for upper
					11		
					12		
					13		
					14		
					15		
					16		
					17		
①	1.6 / 2				18		10YR 5/3 (br) med. SAND - 1" GRAVEL calc. poorly sorted, well rounded, reddish grains prevalent
					19		
					20		
					21		driller's comment - change to clay @ 21.5'
					22		
②	2.0 / 2.0				23		7.5YR (br) massive CLAY fine-bedd. lacus. calc.
					.2		
					24		10YR 5/2 (gr br) coarse SAND - ½" GRAVEL, calc.
					25		

CONTINUATION SHEET

BORING NO.: ~~SG-1b~~ SG-1b

SHEET 2 OF 2

SAMPLER TYPE	FEET RECOVERED / FEET DRIVEN	Qp	SAMPLE NO. / SAMPLE RANGE	N	DEPTH (ft.)	GRAPHIC LOG	DESCRIPTION
					26		
					27		
(3)	1.3 / 2.0				27.8		1/16–1/8" GRAVEL, fairly uniform, rounded, calc.
					28		
					29		10YR 4/3 (br) reddish-looking coarse SAND – 2" GRAVEL, angular, poorly sorted, abrupt contact to above gravel, calc., 10R 4/3 (weak red) colors at base
					30		
					31		
					32		
(4)	1.6 / 2.0				33		10YR 5/2 (gr br) CLAY, faint bedd. calc.
							10YR 5/2 (gr br) med – coarse SAND – 1/2" GRAVEL poorly sorted, well rounded, calc, some redd. stains, grades to clay in color, but abrupt textural change
					34		
					35		
					36		
					37		
(5)	1.7 / 2.0				38		10YR 5/2 (gr br) fine – med SAND, well bedded. 1/8" GRAVEL scattered in lower half calc.
					39		10YR 5/2 (gr br) SILT bedd. lacustrine, calc.
							10YR 5/2 (gr br) TISKILWA TILL, calc. all abrupt textural boundaries between units
					40		
					41		WELL FINISHED IN ABOVE SAND
					42		
					43		
					44		
					45		

LOCATION OF BORING	LOGGED BY	DATE	BORING NO.
Chief Rignier property NW of house and west of dog pen T. 46 N., R. 9 E. Sec. 30 SW¼	RCB	7/18/95	SG-2a
	DRILLING METHOD: auger SS		SHEET 1 OF 1
DATUM	ELEVATION ~761'		

				DRILLING START	FINISH
WATER LEVEL				TIME	TIME
TIME					
DATE				DATE	DATE
CASING DEPTH					

SURFACE CONDITIONS:

SAMPLER TYPE	FEET RECOVERED / FEET DRIVEN	Qp	SAMPLE NO. / SAMPLE RANGE	N	DEPTH (ft.)	GRAPHIC LOG	DESCRIPTION
① pushed SS	1.0 / 2.0				0–2		-10YR 5/6 (yel br) loamy top soil; soil B-horizon, leached; cuttings show med SAND
② pushed SS	0.3 / 2.0				2–4		-10YR 5/6 (yel. br) very uniform med. SAND, highly oxidized, leached; somewhat 'sticky' implying lower B - upper C soil horizon
③ regular SS	1.7 / 2.0				4–6 (.25, .2, .6)		- 10YR 5/6 (yel br) uniform med SAND, leached - 10YR 4/4 (dk yel br) clayey SAND with gr. mottles, leached - 10YR 5/6 (yel br) fine SAND, leached - 5/1 green. gr. gleyed SILTY CLAY, Mn mottles, also
④	1.0 / 2.0				6–8		7.5 YR 6/2 (pink gr) mottles many mottles, calc. 7.5YR 6/4 (lt br) mottled CLAY (4/10 BG dk gr. gley), sands near top - 10YR 5/6 (yel br) uniform med. SAND, leached
					9		driller's comment - sand to gravelly transition @ 9'
					11		Augering terminated @ 10' due to refusal - well built
					12–15		

LOCATION OF BORING	LOGGED BY	DATE	BORING NO.
Riginia property 27' WSW of SG-2a first spl. @ 10'	RCB	7/19/95	SG-2b

DRILLING METHOD:	SHEET
auger SS	1 of 2

				DRILLING START	DRILLING FINISH
WATER LEVEL				TIME	TIME
TIME					
DATE				DATE	DATE
CASING DEPTH					

DATUM ELEVATION

SURFACE CONDITIONS:

SAMPLER TYPE	FEET RECOVERED / FEET DRIVEN	Qp	SAMPLE NO. / SAMPLE RANGE	N	DEPTH (ft.)	GRAPHIC LOG	
①	1.2 / 2.0			76	10 / .25 / .9 / 11		-10YR 6/3 (pale br) CLAY, calc. -10YR 5/6 (yel br) GRAVEL (½") with sand, well-rounded, leached, 2.5YR 5/6 (r.br) at base (v. red), some ¾-1" gravel -10YR 5/6 (yel br) unif. med. SAND, calc.
②	1.0 / 2.0			~5	12 / 13		-10YR 4/4 (dk yel br) unif. med SAND with some coarse sand; lower portion is brighter (10YR 5/6 - yel br), all v. soft, calc.
					14 / 15 / 16 / 17 / 18 / 19		driller's comment - all sand easy augering water @ ~19'
③	1.1 / 2.0			56 more at bott	20 / 21		-10YR 5/4 (yel br) med. SAND, 10YR 5/3 (br) at base, v. uniform calc. few coarse sand grains.
					22 / 23 / 24 / 25		- driller's comment - SAND

CONTINUATION SHEET

BORING NO.: SG-2b

SHEET 2 OF 2

SAMPLER TYPE	FEET RECOVERED / FEET DRIVEN	Qp	SAMPLE NO. / SAMPLE RANGE	N	DEPTH (ft.)	GRAPHIC LOG	DESCRIPTION
					26		
					27		
(4)	0.9 / 2.0			40	.3		10YR 5/3 (br) med SAND, some 1/4" gravel
					28		10YR 5/3 (br) fine-med SAND, few 1/4" gravel, 3/4" gravel at bottom, calc.
					29		
					30		driller's comment - SAND
					31		
					32		
(5)	1.7 / 2.0			59	.5		10YR 5/3 (br) med. SAND, calc.
					.6		10YR 6/3 (pale br) - SILT, calc.
					33		10YR 6/3 (pale br) - 2.5Y 6/2 (lt. br gr) fine SAND, slightly coarser near top, calc., uniform
					34		
					35		
					36		driller's comment - SAND
					37		
(6)	1.3 / 2.0			59	38		GRAVEL washed and fine SAND, calc.
					.3		2.5Y 6/2 (lt br gr) fine SAND with few 1/16" gravel, calc.
					39		
					40		driller's comment - SAND change to GRAVEL at @ 41'
					41		
					42		
(7)	0.5 / 2.0			72	.2		10YR 6/3 (pale br) med - c SAND/GRAVEL to 1.5", calc.
							7.5YR 4/2 (br) TISKILWA TILL, calc.
					43		driller's comment SAND under till and TILL under sand
(8)	0.5 / 1.25			53	44		7.5YR 4-5/2 (br) TISKILWA TILL - calc.
					45		
					.25		

WELL FINISHED IN SAND/GRAVEL ABOVE TILL

LOCATION OF BORING	LOGGED BY	DATE	BORING NO.
Wu property on west side of preserve T. 46 N., R. 9E Sec. 30 NW¼	RCB	7/18/95	SG-3

DRILLING METHOD:	SHEET
augers - SS	1 OF 2

DRILLING	START	FINISH
	TIME	TIME
	DATE	DATE

WATER LEVEL			
TIME			
DATE			
CASING DEPTH			

DATUM

ELEVATION ~762'

SURFACE CONDITIONS:

SAMPLER TYPE	FEET RECOVERED / FEET DRIVEN	Qp	SAMPLE NO. / SAMPLE RANGE	N	DEPTH (ft.)	GRAPHIC LOG	DESCRIPTION
					0		driller's comment - PEAT from cuttings
(1)	0.8 / 2.0			20	1.3		-2.5Y 5/3 (lt. ol. br) sticky moist SAND with ½" gravel -2.5Y 3/1 (v. dk gr) with 7.5YR 4/4 (br) mottles SANDY SILTY CLAY with some >½" gravel leaches
(2)	0.8 / 2.0			37	5		-10YR 5/2 (gr br) laminated CLAY with rounded 'drop stone' gravels (up to 7/8") - calc. upper part of spl. is disturbed
(3)	1.0 / 2.0			76	7		-10YR 5/2 (gr br) laminated CLAY, calc. no gravel
					9		- pressure here blew clay up auger stem
(4)	1.0 / 2.0			11	10		-10YR 5/2 (gr br) laminated CLAY, siltier at top (first SS came up empty here)
					13		driller's comment - change in drilling
(5)	1.2 / 2.0			27	15		-10YR 6/2 (lt br gr) laminated SILT, calc. no gravel

Continuation sheet	Boring No.: SG 3	Sheet 2 of 2				

Sampler type	Feet recovered / Feet driven	Qp	Sample No. / Sample range	N	Depth (ft.)	Description
					16	
					17	
					18	
(6)	2.0 / 2.0			27	19	-10YR 5/2 (gr br) v. fine SAND and SILT, faint bedding, calc. few 'drop stone'
					20	
					21	
					22	water came up hole here - flowing well drill easier @ ~22' - gurgling noise from well - sand seam?
(7)	2.0 / 2.0			26	23	
					24	-10YR 6/2 (lt br gr) SILT, calc. weak bedd., v. uniform.
					25	
					26	
					27	
					28	
					29	drillers comment - pebbles @ ~ 30'
					30	
					31	
					32	-flowing well at 32' . 4 gal / minute
(8)	2.0 / 2.0			27	33	-10YR 5/2 (gr br) coarse SAND to 1/2" GRAVEL calc
					34	NO WELL END OF DRILLING HOLE PLUGGED
					35	

LOCATION OF BORING	LOGGED BY	DATE	BORING NO.
On N. side of Rt 12 ~ 0.4 mi E. of Spring Grove boundary. Hole in ~ 12' n. of pavement T. 46 N., R. 9E. Sec. 30 SE 1/4	RCB	7/20/95	SG-4
DATUM / ELEVATION ?	DRILLING METHOD:		SHEET 1 OF 2

WATER LEVEL				DRILLING START	FINISH
TIME				TIME	TIME
DATE				DATE	DATE
CASING DEPTH					

SURFACE CONDITIONS:

SAMPLER TYPE	FEET RECOVERED / FEET DRIVEN	Qp	SAMPLE NO. / SAMPLE RANGE	N	DEPTH (ft.)	GRAPHIC LOG	DESCRIPTION
					0		
					1–2	Fill	Brown Sand and gravel FILL
					4–7		- driller's comment - change in drilling augers show a 'diamicton' FILL ? 4/5 GY (dk green gr) diamicton with pebble - gleyed fill
①	1.2 / 2.0				.85 / 8–9		- 4/5 GY (dk green gr) diamicton with pebb. FILL ST 2.5/1 (bl) leached organic SILT/PEAT
②	0.7 / 2.0			29	.8 / 10–11		- 5Y 2.5/1 (bl) leached org. SILT/PEAT - 5Y 3/1 (v. dk gr) calc. fine-med. SAND, few c. grains - 'organic looking'
③	0.8 / 2.0			69	12–13		- 2.5Y 4/2 (dk gr br) m. SAND - 1/4" GRAVEL calc. poorly sorted, mid portion has more gravel
					14–15		driller's comment - SAND/GRAVEL

SAMPLER TYPE	FEET RECOVERED / FEET DRIVEN	Qp	SAMPLE NO. / SAMPLE RANGE	N	DEPTH (ft.)	GRAPHIC LOG	CONTINUATION SHEET BORING NO.: SG-4 SHEET 2 OF
					16		driller comment - SAND / GRAVEL
(4)				64	17		bad spl, all washed, wash in 1/4-1/2" GRAVEL, 3" boulder in end of spoon nothing saved
					18		
					19		
					20		
					21		driller's comment - more GRAVEL @ 21'
(5)				127	22		bad spl - washed, wash in fine to 1/4" GRAVEL, lg. boulder in end of spoon
					23		
					24		
					25		WELL FINISHED IN ABOVE SG
					26		
					27		
					28		
					29		
					30		
					31		
					32		
					33		
					34		
					35		

APPENDIX E:

Selected Well Specifications and Ground-Water Level Data for
Wells Used Near Spring Grove Fen
(Grouped by sample location)

Location	Measuring Point Elevation (m)	Latitude (N)	Longitude (W)	Top of Screened Interval (m)	Screened Interval Length (m)	Water Level Below Measuring Point (m)	Water Elevation (m)	Date	Time	Comments
SG-1a	229.41	42° 26' 07.5247"	88° 13' 29.1217"	226.21	0.76	1.07	228.34	Aug. 10,95	8:00A	
						0.95	228.46	Aug. 15,95	12:12P	
						0.99	228.41	Jan. 22, 96	12:48P	
						0.95	228.45	Apr. 16,96	8:59A	
						1.02	228.39	Jul. 10,96	11:40A	
						1.01	228.40	Oct. 17,96	5:30P	
SG-1b	229.48	42° 26' 07.5314"	88° 13' 29.0601"	219.58	0.76	0.88	228.61	Aug. 10,95	8:00A	
						1.12	228.36	Aug. 15,95	11:34A	
								Jan. 22, 96		frozen @ 0.78 m
						0.76	228.73	Apr. 16,96	8:36A	
						0.76	228.73	Jul. 10,96	12:33P	
						0.79	228.70	Oct. 17,96	6:10P	
SG-2a	232.46	42° 26' 14.3487"	88° 13' 46.3711"	230.10	0.76	2.21	230.25	Aug. 15,95	3:45P	
						2.01	230.45	Jan. 23, 96	1:10P	
						2.03	230.42	Apr. 16,96	12:55P	
						1.83	230.63	Jul. 09, 96	4:00P	
						1.83	230.62	Jul. 10,96	10:00A	
						2.01	230.45	Oct. 18,96	8:30A	
SG-2b	232.62	42° 26' 14.3325"	88° 13' 46.7482"	223.58	1.52	2.31	230.30	Aug. 16,95	9:00A	
						2.14	230.48	Jan. 23, 96	11:58A	
						2.17	230.45	Apr. 16,96	12:00P	
						1.95	230.66	Jul. 09, 96	3:30P	
						2.23	230.39	Oct. 18,96	9:47A	
SG-3	229.81	42° 26' 26.0679"	88° 13' 59.5699"			-0.91	230.72	Jul. 19,95	~4:00P	flowing ~ 15 L/min., no well const.
SG-4	229.70	42° 26' 08.3928"	88° 13' 35.6162"	223.45	0.76	0.66	229.04	Aug. 16,95	10:15A	
						0.66	229.04	Jan. 23, 96	11:22A	
						0.68	229.02	Apr. 16,96	11:07A	
						0.69	229.01	Jul. 09, 96	2:00P	
						0.65	229.05	Oct. 17,96	2:30P	
SG-5	229.16	42° 26' 13.2398"	88° 13' 32.6372"	225.06	0.30	1.83	227.33	Aug. 10,95	10:00A	
						1.78	227.38	Aug. 15,95	1:45P	
								Jan. 22, 96		frozen @ 0.79 m
						0.74	228.42	Apr. 16, 96	10:05A	
						1.63	227.53	Jul. 10,96	5:50P	
						1.35	227.81	Oct. 18,96	10:30A	
SG-6	230.09	42° 26' 25.9176"	88° 13'51.7978"	228.26	0.30	0.28	229.81	Aug. 10, 95	3:00P	
						1.56	228.53	Aug. 16,95	12:00P	
						0.74	229.34	Apr. 16,96	~3:15P	
						1.18	228.91	Jul. 10,96	2:45P	
						1.05	229.04	Oct. 18, 96	12:00P	
SG-7		next to SG-6								no well constructed

Location	Measuring Point Elevation (m)	Latitude (N).	Longitude (W)	Top of Screened Interval (m)	Screened Interval Length (m)	Water Level Below Measuring Point (m)	Water Elevation (m)	Date	Time	Comments
SG-8	229.82	42° 26'25.5949"	88° 13'45.1992"	226.59	0.76	0.95	228.87	Apr. 16,96	~3:00P	
						1.03	228.79	Jul. 10,96	3:30P	
						1.44	228.37	Oct. 18,96	12:45P	
SG-9	230.32	42° 26'19.2006"	88° 13'45.3166"	228.70	0.76	0.73	229.58	Apr. 16,96	~2:45P	
						1.22	229.09	Jul. 10,96	4:00P	
						0.95	229.36	Oct. 18,96	1:00P	
SG-10	229.33	42° 26'18.4077"	88° 13'41.6365"	226.89	0.76	1.64	227.69	Apr. 16,96	~2:30P	
						2.06	227.27	Jul. 10,96	5:00P	
						1.99	227.34	Oct. 18,96	1:45P	
SG-11		next to SG-5								no well constructed
R-1	272.09	42° 25' 46.8287"	88° 13' 55.6168"	243.24	1.22	24.79	247.30	Aug. 16,95	1:25P	
						24.76	247.32	Jan. 22,96	3:26P	
						24.81	247.28	Apr. 15,96	12:30P	
						24.54	247.54	Jul. 09, 96	12:31P	
						24.30	247.79	Oct. 17, 96	11:43A	
R-2	263.93	42° 25'46.4204"	88° 13'25.5340"	212.89	1.22	29.85	234.08	Aug. 16, 95	2:23P	
						29.79	234.14	Jan. 22, 96	2:28P	
						29.85	234.08	Apr. 15,96	1:41P	
						29.67	234.26	Jul. 09, 96	1:15P	
						29.56	234.37	Oct. 17,96	1:15P	
N-1	233.82	42° 26'26.6575"	88° 14'13.6419"	na	na	5.78	228.04	Aug. 16, 95	~3:45P	
						5.64	228.18	Jan. 23, 96	8:43A	
						5.47	228.34	Apr. 16,96	2:55P	
						5.68	228.13	Jul. 10,96	8:00A	
						5.71	228.11	Oct. 17,96	4:00P	
						5.71	228.10	Oct. 18,96	8:00A	
N-2	230.17	42° 26'04.5433"	88° 13'08.6576"	na	na	4.29	225.88	Aug. 16,95	3:15P	
						4.02	226.15	Jan. 23, 96	9:45A	
						3.86	226.31	Apr. 15,96	2:50P	
						3.74	226.43	Apr. 16,96	~2:55P	
						4.11	226.05	Jul. 10,96	9:00A	
						4.13	226.03	Oct. 17,96	~4:30P	rain in afternoon
						4.14	226.02	Oct. 18,96	8:15A	

APPENDIX F:

Volatile Organic Compounds Analyzed at Spring Grove Fen

dichlorodifluoromethane
chloromethane
vinyl chloride
bromomethane
chloroethane
trichlorofluoromethane
1,1-dichloroethene
dichloromethane
t-1,2-dichioroethene
1,1-dichloroethane
2,2-dichloropropane
c-l,2-dichloroethene
chloroform
bromochloromethane
1,1,1-trichloroethane
1,1 -dichloropropene
carbon tetrachloride
1,2-dichloroethane
benzene
trichloroethene
1,2-dichloropropane
bromodichloromethane
dibromomethane
c-1,3-dichloropropene
toluene
t-l,3-dichloropropene
1,1,2-trichloroethane
1,3-dichloropropane
tetrachloroethylene
dibromochloromethane
1,2-dibromoethane
chlorobenzene
1,1,1,2-tetrachloroethane
ethyl benzene
m + p xylene
o-xylene
styrene
isopropyl benzene
bromoform
1,1,2,2-tetrachloroethane
1,2,3-trichloropropane
n-propyl benzene
bromobenzene
1,3,5-trimethylbenzene
2-chlorotoluene
4-chlorotoluene
t-butyl benzene
1,2,4-trimethylbenzene
sec-butyl benzene
para-isopropyltoluene
1,3-dichlorobenzene
1,4-dichlorobenzene
n-butyl benzene
1,2-dichlorobenzene
1,2-dibromo-3-chloropropane
1,2,4-trichlorobenzene
hexachlorobutadiene
naphthalene
1,2,3-trichlorobenzene

APPENDIX G:

Water Quality Data Collected at Spring Grove Fen Between 6/94 and 11/96
(Grouped by sample location)

Sample ID	Origin	Field Chemistry Data Date	Time	pH units	Temp. ° c	ORP mV	Cond. umhos/cm	Lab Chemistry Data Ba mg/L	Ca mg/L	Cu mg/L	Fe mg/L	K mg/L	Mg mg/L	Mn mg/L
	MDL			0.01	0.1	1	1 (%)	0.003	0.07	0.007	0.007	1.29	0.03	0.002
2	TB	Aug. 14,95						--	0.09	--	--	--	0.04	--
14	TB	Jan. 22, 96						--	--	--	--	--	--	--
29	TB	Apr. 16,96						--	--	--	--	--	--	--
39	TB	Jun. 08,96	3:00P					--	--	--	--	--	--	--
52	TB	Oct. 16,96	5:00P					--	--	--	--	--	--	--
4	SG-1a	Aug. 15,95	12:12P	7.07	12.6	305		0.050	107.59	--	0.018	--	52.39	0.064
15	SG-1a	Jan. 22,96	12:48P	7.24	8.4	305	605	0.041	98.97	--	0.008	--	47.83	0.009
15-LS	SG-1a (LS)							0.044	102.41	--	0.013	--	49.68	0.011
28	SG-1a	Apr. 16,96	8:59A	7.30	7.7	243	520	0.039	100.11	--	0.016	--	49.09	0.012
47	SG-1a	Jun. 10,96	11:40A	7.22	11.0	276	750	0.050	112.45	--	0.011	--	55.95	0.013
48	SG-1a (FD)	Jun. 10,96	11:40A					0.050	114.31	--	--	--	56.85	0.011
58	SG-1a	Oct. 17,96	5:30P	7.29	11.4	192	660	0.043	95.83	--	--	--	46.64	0.006
3	SG-1b	Aug. 15,95	11:34A	7.15	10.4	82		0.077	97.46	--	0.131	--	47.81	0.434
27	SG-1b	Apr. 16,96	8:36A	7.36	9.6	105	480	0.067	93.87	--	0.218	--	46.00	0.141
49	SG-lb	Jun. 10,96	12:33P	7.37	11.5	72	470	0.065	86.90	--	0.309	--	42.98	0.115
59	SG-lb	Oct. 17,96	6:10P	7.41	10.7	2	510	0.070	90.91	--	0.425	--	44.85	0.109
6	SG-2a	Aug. 15,95	3:45P	7.26	16.8	69		0.114	110.15	--	1.958	--	55.08	2.214
23	SG-2a	Jan. 23, 96	1:10P	7.18	7.0	205	610	0.097	91.46	--	1.224	--	46.47	1.064
23-LS	SG-2a(LS for method 507 only)													
33	SG-2a	Apr. 16,96	12:55P	7.41	7.2	111	610	0.096	91.40	--	1.245	--	47.98	1.035
34	SG-2a (FD)	Apr. 16,96	12:55P					0.092	93.09	--	0.560	--	47.77	0.650
46	SG-2a	Jun. 10,96	10:00A	7.28	13.7	92	715	0.103	89.40	--	0.699	--	44.76	0.691
60	SG-2a	Oct. 18,96	8:30A	7.20	13.7	-3	800	0.119	96,96	--	0.893	--	48.72	1.082
7	SG-2b	Aug. 16,95	9:00A	7.77	11.1	355		0.049	94.32	--	--	--	46.36	0.090
22	SG-2b	Jan. 23, 96	11:58A	7.37	9.7	225	495	0.037	80.69	--	--	1.47	39.61	0.055
32	SG-2b	Apr. 16,96	12:00P	7.51	10.2	255	490	0.036	84.98	--	0.010	--	42.10	0.033
43	SG-2b	Jun. 09, 96	3:30P	7.45	11.2	230	500	0.032	85.83	--	--	--	42.25	0.013
61	SG-2b	Oct. 18, 96	9:47A	7.39	10.9	85	540	0.037	89.34	--	--	--	44.11	0.016

TB = trip blank, -- = below MDL, LS = lab split, FD = field duplicate, ULS = USGS lab split, and FS = field spike

Sample ID	Origin	Na mg/L	S mg/L	Si mg/L	Sr mg/L	Zn mg/L	F mg/L	Cl mg/L	N03 mg N/L	S04 mg/L	0-P04 mg P/L	TKN mg/L	NH4 mgN/L	labpH units
	MDL	0.08	0.26	0.03	0.003	0.006	0.1	0.3	0.02	0.9	0.003	0.1	0.02	
2	TB	--	--	--	--	--	--	--	--	--	--	--	0.02	5.67
14	TB	--	--	0.13	--	--	--	--	--	--	--	--	--	5.56
29	TB	--	--	--	--	--	--	--	--	--	0.006	--	--	5.58
39	TB	--	0.30	--	--	0.250	--	--	--	--				5.77
52	TB	--	--	--	--	0.007	--	--	--	--	0.002	--	--	5.47
4	SG-1a	35.38	17.26	9.64	0.098	--	0.1	46.4	0.15	50.4	0.024	0.1	0.02	7.44
15	SG-1a	22.16	15.35	9.02	0.089	0.011	0.1	37.8	0.13	51.3	0.108	--	--	7.64
15-LS	SG-1a (LS)	23.01	15.95	9.33	0.091	0.012	0.1	38.9	0.12	52.5	0.109	--	--	7.67
28	SG-1a	15.90	16.80	8.97	0.086	0.008	0.8	21.3	0.10	50.8	0.067	--	--	7.80
47	SG-1a	35.47	16.01	8.20	0.097	0.011	--	118.6	0.18	50.8				7.70
48	SG-1a (FD)	36.71	15.67	8.36	0.097	0.009	--	119.4	0.18	51.1				7.51
58	SG-1a	33.45	16.38	8.69	0.080	0.037	--	42.6	0.14	50.7	0.029	0.3	--	7.48
3	SG-1b	4.36	18.00	9.56	0.097	--	0.1	5.8	--	55.0	0.026	--	0.02	7.27
27	SG-1b	4.39	20.65	9.69	0.106	0.008	0.5	5.3	--	62.0	0.065	--	0.04	7.98
49	SG-1b	4.12	21.70	8.78	0.097	0.011	0.1	6.5	--	67.4				7.27
59	SG-1b	4.22	21.32	8.96	0.109	0.049	0.1	6.6	--	65.7	0.018	--	0.03	7.45
6	SG-2a	40.34	16.57	9.96	0.162	--	0.1	99.3	4.03	51.3	0.027	--	0.02	7.74
23	SG-2a	31.78	16.72	7.33	0.127	0.012	0.1	87.4	4.40	55.5	0.097	0.3	0.09	7.55
23-LS	SG-2a (LS for													
33	SG-2a	34.02	18.37	6.89	0.132	0.007	0.7	87.4	4.98	58.4	0.059	0.2	0.11	7.83
34	SG-2a (FD)	35.22	19.36	6.95	0.118	--	0.7	78.2	4.19	53.5	0.055	0.4	0.10	7.76
46	SG-2a	47.54	11.98	7.32	0.123	0.009	--	96.5	6.71	40.0				7.50
60	SG-2a	51.82	16.15	7.93	0.149	0.107	--	121.0	2.00	45.4	0.017	0.5	0.18	7.35
7	SG-2b	5.51	28.43	9.12	0.171	--	0.1	12.8	1.09	80.2	0.012	--	0.02	7.87
22	SG-2b	5.01	24.04	7.86	0.145	--	0.1	11.9	0.45	82.1	0.095	--	--	7.82
32	SG-2b	5.14	27.74	8.30	0.153	0.007	0.6	10.9	0.17	79.8	0.060	--	--	7.68
43	SG-2b	5.01	26.67	7.88	0.151	0.011	0.1	14.3	3.47	77.4				7.91
61	SG-2b	5.49	24.53	8.04	0.152	0.106	0.1	16.7	5.68	74.1	0.016	0.2	--	7.71

TB = trip blank, -- = below MDL, LS = lab split, FD = field duplicate, ULS = USGS lab split, and FS = field spike

Sample ID	Origin	Alkalinty mg CaC03/L	NVOC mg/L	TDS 104 ° c	TDS 180° C	ELISA triazines ug/L	ELISA alachlor ug/L	ELISA 2,4-D ug/L	ELISA alachlor ESA ug/L	GC 507 atrazine ug/L	GC507 simazine ug/L
	MDL	2	0.20	2	2	0.1	0.1	0.5	0.10	0.1	0.1
2	TB	2	--	3	--	--	--	--			
14	TB	2	0.34	7	6	--	--	--			
29	TB	--	0.20	6	2	--	--	--			
39	TB	3	--	5	4	--	--	--			
52	TB	4	--	4	3		–			--	--
4	SG-1a	411	1.60	550	521	--	--	--			
15	SG-1a	414	0.65	542	530	--	--	--			
15-LS	SG-1a (LS)	414		537	524	--	--	0.5			
28	SG-1a	408	0.80	522	501	--	--	--			
47	SG-1a	410	1.10	723	. 643	--	--	--			
48	SG-1a (FD)	407	1.20	736	650	--	--	--			
58	SG-1a	439	0.70	546	524		--			--	--
3	SG-1b	383	0.89	463	434	--	--	--			
27	SG-1b	356	0.80	487	442	--	--	--			
49	SG-1b	345	1.00	476	452	--	--	--			
59	SG-1b	376	0.60	459	437		0.2		--	--	--
6	SG-2a	345	2.90	628	561	--	0.7	--			
23	SG-2a	324	1.14	623	581	--	1.0	--		--	--
23-LS	SG-2a (LS for					--	1.0	--		--	--
33	SG-2a	324	1.30	638	566	--	0.5	--		--	--
34	SG-2a (FD)	328	1.30	629	546	--	0.5	--		--	--
46	SG-2a	352	1.70	631	575	--	0.3	--		--	--
60	SG-2a	354	2.00	634	592		0.6		1.29	--	--
7	SG-2b	311	0.67	449	415	--	0.1	--			
22	SG-2b	307	0.49	432	428	--	0.4	--		–	--
32	SG-2b	301	0.60	455	445	--	--	--			
43	SG-2b	308	0.90	479	473	--	--	--		--	--
61	SG-2b	328	0.50	496	454		0.6		0.65	--	--

TB = trip blank, -- = below MDL, LS = lab split, FD = field duplicate, ULS = USGS lab split, and FS = field spike

Sample ID	Origin	GC 507 prometon ug/L	GC 507 alachlor ug/L	GC 507 aiazinon ug/L	acetochlor ESA ug/L	acetochlor OXA ug/L	alachlor ESA ug/L	alachlor OXA ug/L	hydroxy-atrazinc ug/L	metolachlor ESA ug/L	metolachlor OXA ug/L
	MDL	0.1	0.4	0.007	0.20	0.20	0.20	0.20	0.20	0.20	0.20
2	TB										
14	TB										
29	TB										
39	TB										
52	TB	--	--	--							
4	SG-1a										
15	SG-1a										
15-LS	SG-1a (LS)										
28	SG-1a										
47	SG-1a										
48	SG-1a (FD)										
58	SG-1a	--	--	--							
3	SG-1b										
27	SG-1b										
49	SG-1b										
59	SG-1b	--	--	--	--	--	--	--	--	--	--
6	SG-2a										
23	SG-2a	--	--								
23-LS	SG-2a (LS for	--	--								
33	SG-2a	--	--								
34	SG-2a (FD)	--	--								
46	SG-2a	--	--								
60	SG-2a	--	--	--	--	--	1.03	--	--	1.10	--
7	SG-2b										
22	SG-2b	--	--								
32	SG-2b										
43	SG-2b	--	--								
61	SG-2b	--	--	--	--	--	0.27	--	--	0.23	--

TB = trip blank, -- = below MDL, LS = lab split, FD = field duplicate, ULS = USGS lab split, and FS = field spike

Sample ID	Origin	Field Chemistry Data Date	Time	pH units	Temp. ° c	ORP mV	Cond. umhos/cm	Lab Chemistry Data Ba mg/L	Ca mg/L	Cu mg/L	Fe mg/L	K mg/L	Mg mg/L	Mn mg/L
	MDL			0.01	0.1	1	1 (%)	0.003	0.07	0.007	0.007	1.29	0.03	0.002
1	SG-3	Jul. 19,95	4:00P					0.042	72.54	--	0.016		35.71	0.035
8	SG-4	Aug. 16,95	10:15A	7.66	13.0	-50		0.079	101.80	--	1.767		50.41	0.061
9	SG-4 (FD)	Aug. 16,95	10:30A					0.078	101.05	--	1.779		49.93	0.060
21	SG-4	Jan. 23, 96	11:22A	7.31	9.6	157	540	0.057	88.97	--	1.254		44.69	0.052
31	SG-4	Apr. 16,96	11:07A	7.46	8.0	-37	475	0.057	92.09	--	1.453		46.66	0.053
42	SG-4	Jun. 09, 96	2:00P	7.40	10.3	-73	510	0.053	91.00	--	1.399		45.28	0.054
55	SG-4	Oct. 17,96	2:30P	7.44	14.1	-82	640	0.055	89.50	--	1.386		43.95	0.052
55-LS	SG-4 (LS)							0.055	89.18	--	1.381		43.94	0.052
5	SG-5	Aug. 15,95	1:45P	~7.23	12.2	25		0.063	112.34	--	1.327		47.93	0.304
5-LS	SG-5							0.060	111.30	--	1.322		47.81	0.301
30	SG-5	Apr. 16,96	10:05A	7.30	5.0	47	470	0.051	99.71	--	1.164		43.84	0.287
51	SG-5	Jun. 10,96	5:50P	7.22	10.9	<21	520	0.045	100.73	--	1.103		43.65	0.452
62	SG-5	Oct. 18,96	10:30A	7.22	11.4	-64	580	0.051	94.89	--	1.068		40.57	0.299
63	SG-5 (FD)	Oct. 18,96	10:45A					0.049	90.18		1.052		38.86	0.287
	SG-5 (ULS)													
10	SG-6	Aug. 16,95	12:00P	7.98	24.1	228		0.048	76.25	--	0.148		36.02	0.052
50	SG-6	Jun. 10,96	2:45P	7.48	18.9	<142		0.042	76.07	--	0.224		37.10	0.053
64	SG-6	Oct. 18,96	12:00P	7.16	13.5	33	495	0.046	76.29	--	0.145		37.12	0.053
11	R-1	Aug. 16,95	1:25P	8.47	13.6	330		0.023	91.58	--	--		45.84	--
17	R-l	Jan. 22, 96	3:26P	7.32	10.3	367	530	0.028	90.79	--	--		45.70	--
24	R-l	Apr. 15,96	12:30P	7.20	10.7	334	535	0.028	93.41	0.021	0.009		46.88	--
40	R-l	Jun. 09, 96	12:31P	7.24	14.8	260	620	0.026	94.90	0.008	--		47.80	--
53	R-l	Oct. 17,96	11:43 A	7.43	16.2	190	605	0.024	86.58	0.030	--		43.44	--
12	R-2	Aug. 16,95	2:23P	8.06	13.3	346		0.031	98.55	--	--		48.46	0.015
16	R-2	Jan. 22, 96	2:28P	7.13	9.9	339	555	0.032	99.27	--	--		48.69	0.012
25	R-2	Apr. 15,96	1:41P	7.02	10.8	336	580	0.031	103.65	0.045	--		50.71	0.003
25-LS	R-2 (LS)							0.030	102.24	0.044	0.005		50.00	0.004
41	R-2	Jun. 09, 96	1:15P	7.07	12.9	308	595	0.031	102.45	0.042	0.008		50.37	0.010

TB = trip blank, -- = below MDL, LS = lab split, FD = field duplicate, ULS = USGS lab split, and FS = field spike

Sample ID	Origin	Na mg/L	S mg/L	Si mg/L	Sr mg/L	Zn mg/L	F mg/L	C1 mg/L	N03 mg N/L	S04 mg/L	0-PO4 mg P/L	TKN mg/L	NH4 mg N/L	lab pH units
	MDL	0.08	0.26	0.03	0.003	0.006	0.1	0.3	0.02	0.9	0.003	0.1	0.02	
1	SG-3	4.45	11.11	8.75	0.117		0.1	2.6		36.0	0.364		0.02	7.85
8	SG-4	5.14	26.53	11.36	0.154	--	0.1	7.6	--	75.0	0.052	--	0.02	7.70
9	SG-4 (FD)	5.16	25.85	11.27	0.153	--	0.2	7.6	--	74.7	0.054	0.1	0.02	7.54
21	SG-4	4.37	22.87	8.94	0.130	0.006	0.1	7.2	--	75.6	0.092	--	0.04	7.92
31	SG-4	4.35	24.59	9.08	0.134	0.013	0.5	6.3	--	73.1	0.098	--	0.07	8.02
42	SG-4	4.28	26.24	9.34	0.130	0.013	0.1	6.7	--	74.7				7.58
55	SG-4	4.07	23.61	9.87	0.129	0.085	0.1	6.8	--	74.9	0.028	0.2	0.05	8.06
55-LS	SG-4 (LS)	4.09	23.91	9.86	0.130	0.068	0.1	6.7	–	74.3	0.028	–	0.05	7.96
5	SG-5	10.07	32.58	8.65	0.141	--	0.2	26.9	--	89.6	0.025	0.2	0.06	7.58
5-LS	SG-5	9.99	32.42	8.59	0.142	--	0.2	27.4	--	90.1	0.026	0.2	0.06	7.71
30	SG-5	8.89	31.48	6.48	0.124	0.007	0.6	25.4	–	95.1	0.077	0.1	0.10	7.66
51	SG-5	8.88	31.70	6.76	0.125	0.030	0.1	26.1	--	94.2				7.73
62	SG-5	9.22	27.00	7.31	0.119	0.066	0.1	24.5	--	82.8	0.021	0.5	0.09	7.52
63	SG-5 (FD)	8.72	26.22	6.98	0.116	0.046	0.1	24.7		83.2	0.023	0.3	0.09	7.28
	SG-5 (ULS)													
10	SG-6	3.69	16.46	8.02	0.087	0.028	0.1	7.0	--	50.6	0.040	0.2	0.03	7.55
50	SG-6	3.94	19.41	6.81	0.078	0.010	0.1	6.7	--	58.6				7.86
64	SG-6	3.45	12.53	7.29	0.076	0.041	0.1	6.0	–	39.6	0.024	0.3	0.05	7.27
11	R-1	2.95	21.54	8.65	0.068	--	0.1	14.7	6.48	65.3	0.016	0.2	0.02	7.61
17	R-1	3.11	21.66	8.42	0.066	0.013	0.1	15.8	4.76	69.3	0.084	0.3	--	7.73
24	R-l	3.31	22.23	8.59	0.067	0.041	0.8	16.2	4.70	68.4	0.067	0.1	--	7.85
40	R-l	4.31	24.92	8.25	0.070	0.031	--	27.5	4.78	72.5				7.85
53	R-l	3.21	20.51	7.90	0.064	0.620	–	18.0	4.90	67.1	0.014	0.2	--	7.86
12	R-2	3.85	17.55	8.50	0.071	0.012	0.2	5.6	0.71	56.9	0.014	--	0.02	7.49
16	R-2	3.68	16.83	8.57	0.072	0.020	0.1	5.3	0.68	54.5	0.093	--	--	7.62
25	R-2	3.74	16.79	9.08	0.075	0.062	0.8	4.6	0.87	51.4	0.061	--	--	7.96
25-LS	R-2 (LS)	3.71	16.68	8.99	0.075	0.063	0.8	4.4	0.80	49.1	0.062	--	--	7.86
41	R-2	3.62	18.14	8.77	0.075	0.051	--	5.4	0.86	51.7				8.02

TB = trip blank, -- = below MDL, LS = lab split, FD = field duplicate, ULS = USGS lab split, and FS = field spike

Sample ID	Origin	Alkalinty mg CaC03/L	NVOC mg/L	TDS 104 ∘ c	TDS 180 ∘ c	ELISA triazines ug/L	ELISA alachlor ug/L	ELISA 2,4-D ug/L	ELISA alachlor ESA ug/L	GC 507 alrazine ug/L	GC 507 simazine ug/L
	MDL	2	0.20	2	2	0.1	0.1	0.5	0.10	0.1	0.1
1	SG-3	304	0.94	354	331			--			
8	SG-4	357	0.77	470	437	--	0.2	0.7			
9	SG-4 (FD)	359	0.79	478	448	--	--	--			
21	SG-4	358	0.63	480	468	--	--	--			
31	SG-4	353	0.80	497	458	--	--	--			
42	SG-4	356	1.10	496	486	--	--	--			
55	SG-4	372	0.60	460	442		--			--	--
55-LS	SG-4 (LS)	367	0.60	459	442		--			--	--
5	SG-5	338	2.30	532	474	--	0.2	--			
5-LS	SG-5	340	2.10	510	460	--	0.3	--			
30	SG-5	329	2.90	548	508	--	0.2	--		--	--
51	SG-5	341	3.10	556	513	--	0.1	--			
62	SG-5	347	1.70	500	472		0.3		1.20	--	--
63	SG-5 (FD)	343	1.70	492	469		0.4		0.83		
	SG-5 (ULS)										
10	SG-6	294	3.40	371	350	--	--	--			
50	SG-6	300	6.20	411	409	--	--	--			
64	SG-6	342	4.40	396	380		--			--	--
11	R-1	322	0.68	475	442	--	--	--			
17	R-1	332	0.50	478	459	--	--	--			
24	R-1	334	0.70	510	466	--	--	--			
40	R-l	336	0.90	546	489	--	--	--			
53	R-l	350	0.50	500	450		0.1		0.22	--	--
12	R-2	406	0.94	487	454	--	--	--			
16	R-2	411	0.68	501	493	--	--	--			
25	R-2	412	0.80	527	479	--	--	--			
25-LS	R-2 (LS)	412	1.00	503	484	--	--	--			
41	R-2	419	1.20	513	510	--	--	--			

TB = trip blank, -- = below MDL, LS = lab split, FD = field duplicate, ULS = USGS lab split, and FS = field spike

Sample ID	Origin	GC 507 prometon ug/L	GC 507 alachlor ug/L	GC 507 aiazinon ug/L	acetochlor ESA ug/L	acetochlor OXA ug/L	alachlor ESA ug/L	alachlor OXA ug/L	hydroxy-atrazine ug/L	metolachlor ESA ug/L	metolachlor OXA ug/L
	MDL	0.1	0.4	0.007	0.20	0.20	0.20	0.20	0.20	0.20	0.20
1	SG-3										
8	SG-4										
9	SG-4 (FD)										
21	SG-4										
31	SG-4										
42	SG-4										
55	SG-4	--	--	0.010							
55-LS	SG-4 (LS)	--	--	--							
5	SG-5										
5-LS	SG-5										
30	SG-5	--	--								
51	SG-5										
62	SG-5	--	--	--	--	--	0.60	--	--	1.11	--
63	SG-5 (FD)	--	--	--	--	--	0.65	--	--	0.91	--
	SG-5 (ULS)				--	–	0.55	--	--	0.74	--
10	SG-6										
50	SG-6										
64	SG-6	–	–	–							
11	R-1										
17	R-1										
24	R-l										
40	R-l										
53	R-l	–	–	–	–	–	–	--	--	0.78	--
12	R-2										
16	R-2										
25	R-2										
25-LS	R-2 (LS)										
41	R-2										

TB = trip blank, -- = below MDL, LS = lab split, FD = field duplicate, ULS = USGS lab split, and FS = field spike

Sample ID	Origin	Field Chemistry Data: Date	Time	pH (units)	Temp. (° C)	ORP (mV)	Cond. (umhos/cm)	Lab Chemistry Data: Ba (mg/L)	Ca (mg/L)	Cu (mg/L)	Fe (mg/L)	K (mg/L)	Mg (mg/L)	Mn (mg/L)
	MDL			0.01	0.1	1	1 (%)	0.003	0.07	0.007	0.007	1.29	0.03	0.002
54	R-2	Oct. 17,96	1:15P	7.18	12.4	185	615	0.030	99.02	0.029			48.44	0.009
18	N-1	Jan. 23, 96	8:43A	8.20	1.5	348	510	0.048	83.75	--	0.014	--	44.34	0.028
35	N-1	Apr. 16, 96	2:55P	8.56	9.4	249	470	0.046	67.57	--	0.017	2.09	37.75	0.059
35-LS	N-1 (LS)							0.047	68.30	--	0.022	1.44	37.94	0.062
44	N-1	Jun. 10,96	8:00A	8.25	18.0	265	570	0.052	72.17	--	0.015	--	40.77	0.018
56	N-1	Oct. 17,96	4:00P	8.35	16.6	209	580	0.051	64.73	--	0.037	--	39.72	0.045
57	N-1	Oct. 17, 96	4:30P	8.29	16.5	183	575	0.051	65.63	--	0.042	--	40.42	0.047
13	N-2	Aug. 16,95	3:15P	8.29	26.2	300		0.058	71.22	--	0.035	2.14	40.10	0.025
19	N-2	Jan. 23, 96	9:45A	8.16	1.5	352	515	0.049	83.02	--	0.007	--	43.79	0.029
20	N-2 (FD)	Jan. 23, 96	9:45A					0.048	84.43	--	--	--	44.69	0.030
26	N-2	Apr. 15,96	2:50P	6.70	4.7	299	465	0.040	65.81	--	0.027	--	37.23	0.069
45	N-2	Jun. 10,96	9:00A	8.25	18.4	300	570	0.053	71.67	--	0.012	--	40.18	0.016
45-LS	N-2 (LS)							0.052	72.04	--	0.020	2.16	40.37	0.015
36	N03 FS 1	Apr. 16, 96	3:45P											
37	N03 FS 2	Apr. 16, 96	3:45P											
38	N03 FS 3	Apr. 16,96	3:45P											
	MINIMUM			6.70	1.5	-82	465	0.023	64.73	0.008	0.005	1.44	35.71	0.003
	MAXIMUM			8.56	26.2	367	800	0.119	114.31	0.045	1.958	2.16	56.85	2.214

TB = trip blank, -- = below MDL, LS = lab split, FD = field duplicate, ULS = USGS lab split, and FS = field spike

Sample ID	Origin	Na mg/L	S mg/L	Si mg/L	Sr mg/L	Zn ing/L	F mg/L	Cl mg/L	N03 mg N/L	S04 mg/L	0-P04 mg P/L	TKN mg/L	NH4 mg N/L	lab pH units
	MDL	0.08	0.26	0.03	0.003	0.006	0.1	0.3	0.02	0.9	0.003	0.1	0.02	
54	R-2	3.41	15.67	8.67	0.072	0.225		6.6	1.07	51.1	0.018	0.2		7.68
18	N-l	39.73	22.57	4.47	0.195	0.010	0.2	82.8	3.80	71.8	0.130	1.1	0.20	8.43
35	N-l	26.24	20.18	3.19	0.163	0.006	0.5	54.9	3.11	60.5	~1.0	1.9	0.06	8.31
35-LS	N-l (LS)	28.83	21.02	3.20	0.165	--	0.5	54.5	3.10	66.1	~1.0	2.2	0.06	8.30
44	N-l	19.77	18.54	3.62	0.160	0.012	0.1	45.9	3.84	52.5				8.33
56	N-l	23.76	16.70	2.67	0.158	0.042	0.1	53.9	1.64	53.1	0.044	1.3	0.02	8.10
57	N-l	23.11	17.52	2.74	0.159	0.065	0.1	54.1	1.63	53.3	0.130	1.7	0.02	8.19
13	N-2	23.15	16.77	5.79	0.165	--	0.1	53.3	2.02	52.5	0.236	0.2	0.03	8.28
19	N-2	38.79	22.11	4.45	0.193	0.006	0.2	82.7	3.78	71.8	0.127	1.0	0.21	8.23
20	N-2 (FD)	39.68	22.58	4.55	0.195	--	0.2	81.3	3.77	72.1	0.114	1.0	0.19	8.24
26	N-2	24.25	18.74	2.90	0.154	0.006	0.6	54.0	1.51	55.5	0.110	1.2	0.06	8.25
45	N-2	19.61	18.51	3.66	0.155	0.010	0.1	46.5	3.76	52.4				8.21
45 -LS	N-2 (LS)	19.56	16.41	3.69	0.158	0.010	0.1	46.9	3.81	53.2				8.31
36	N03 FS 1								0.56					
37	N03 FS 2								6.65					
38	N03 FS 3								16.80					
	MINIMUM	2.95	11.11	2.67	0.064	0.006	0.1	2.6	0.10	36.0	0.012	0.1	0.02	7.27
	MAXIMUM	51.82	32.58	11.36	0.195	0.620	0.8	121.0	6.71	95.1	0.364	2.2	0.21	8.43

TB = trip blank, -- = below MDL, LS = lab split, FD = field duplicate, ULS = USGS lab split, and FS = field spike

Sample ID	Origin	Alkalinty mg CaCO3/L	NVOC mg/L	TDS 104 ° C	TDS 180 ° C	ELISA triazines ug/L	ELISA alachlor ug/L	ELISA 2,4-D ug/L	ELISA alachlor ESA ug/L	GC 507 atrazine ug/L	GC 507 simazine ug/L
	MDL	2	0.20	2	2	0.1	0.1	0.5	0.10	0.1	0.1
54	R-2	436	0.70	492	468					--	--
18	N-1	302	4.63	588	548	--	0.2	--		--	--
35	N-1	245	11.10	532	439	0.2	0.4	--		0.2	--
35-LS	N-1 (LS)	246	10.90	492	451	0.2	0.4	--			
44	N-1	287	4.80	503	431	0.9	0.4	--		0.5	--
56	N-1	288	4.50	468	422		0.6		1.14	0.1	0.2
57	N-1	289	4.60	449	419		0.6		0.80	0.1	0.2
13	N-2	282	4.50	457	425	--	0.5	--			
19	N-2	302	4.53	588	541	--	0.2	--		--	--
20	N-2 (FD)	302	4.57	548	538	0.2	0.9	--		--	--
26	N-2	250	6.30	477	419	--	0.2	--		--	--
45	N-2	286	4.70	470	459	0.8	0.3	--		0.4	--
45-LS	N-2 (LS)	283	4.90	473	456	0.7	0.3	--		0.4	--
36	N03 FS 1										
37	N03 FS 2										
38	N03 FS 3										
	MINIMUM	245	0.49	354	331	0.2	0.1	0.5	0.22	0.1	0.2
	MAXIMUM	439	11.10	736	650	0.9	1.0	0.7	1.29	0.5	0.2

TB = trip blank, -- = below MDL, LS = lab split, FD = field duplicate, ULS = USGS lab split, and FS = field spike

Sample ID	Origin	GC 507 prometon ug/L	GC 507 alachlor ug/L	GC 507 aiazinon ug/L	acctochlor ESA ug/L	acetochlor OXA ug/L	alachlor ESA ug/L	alachlor OXA ug/L	hydroxy- atrazine ug/L	metolachlor ESA ug/L	metolachlor OXA ug/L
	MDL	0.1	0.4	0.007	0.20	0.20	0.20	0.20	0.20	0.20	0.20
54	R-2										
18	N-1	--	--								
35	N-1	--	--								
35-LS	N-1 (LS)										
44	N-l	--	--								
56	N-l	--	--	0.009	--	--	0.93	--	--	2.52	0.64
57	N-l	--	--	--	--	--	0.94	--	--	2.57	0.64
13	N-2										
19	N-2	--	--								
20	N-2 (FD)	--	--								
26	N-2	--	--								
45	N-2	--	--								
45-LS	N-2 (LS)	--	--								
36	N03 FS 1										
37	N03 FS 2										
38	N03 FS 3										
	MINIMUM	0.0	0.0	0.009	0.00	0.00	0.27	0.00	0.00	0.23	0.64
	MAXIMUM	0.0	0.0	0.010	0.00	0.00	1.03	0.00	0.00	2.57	0.64

TB = trip blank, -- = below MDL, LS = lab split, FD = field duplicate, ULS = USGS lab split, and FS = field spike

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